# Hydrometeorological Prediction Requirements


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*Center for Hydrometeorology and Remote Sensing*
*University of California Irvine*


***Satellite Observation of the Global Water Cycle,***
***Irvine CALIF USA, 7-9 March, 2007***


# Two Primary Water Resources/Hydrology Challenges:

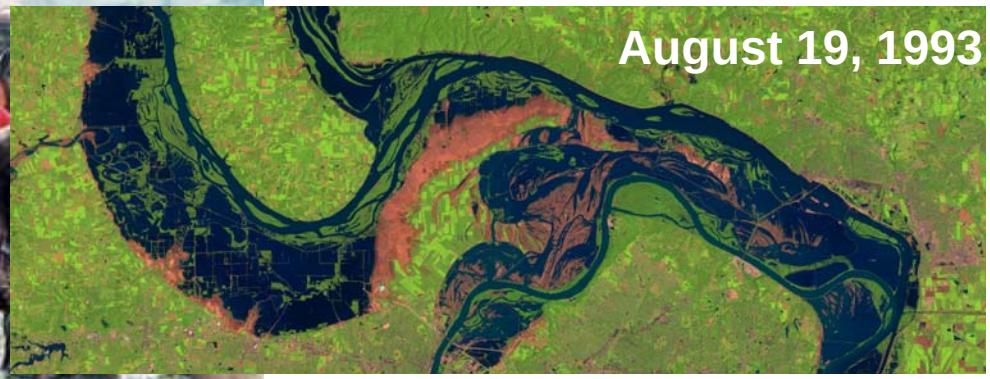
- ***Hydrologic Hazards ( Floods and Droughts)***

- ***Water Supply Requirements ( Quantity and Quality)***

# *Hydrologic Forecasting Needs: Flash Floods*

# *"General" and Widespread Floods*

***Bangladesh floods in 2004***

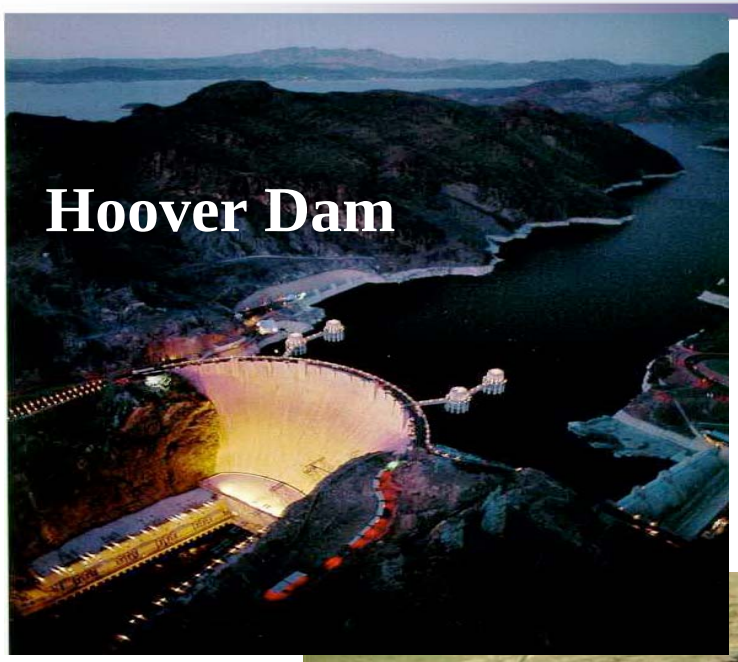



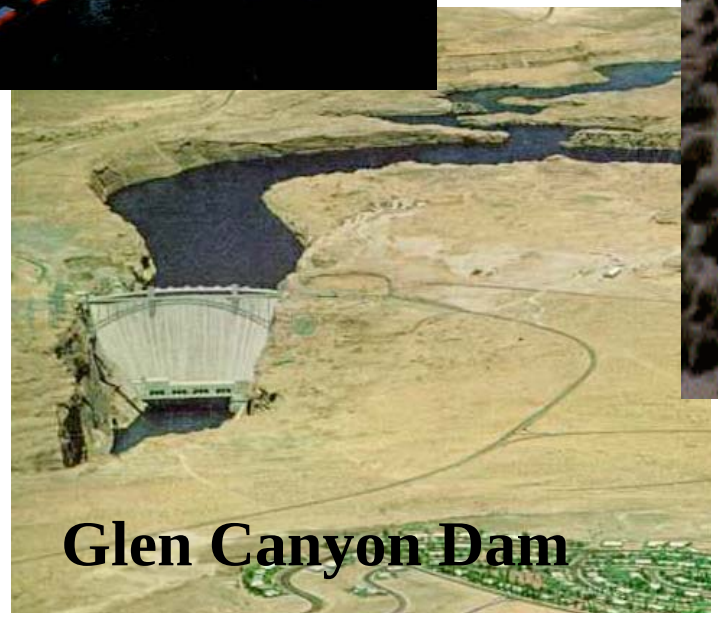

***MISSISSIPPI Floods 1993***


# *Primary Solution To Meet Hydrologic Extreme and Water Resources Needs*

## *Engineering Approach: Control, Store, Pump and Transfer*

# *Water Resources Operation, planning and Development:*

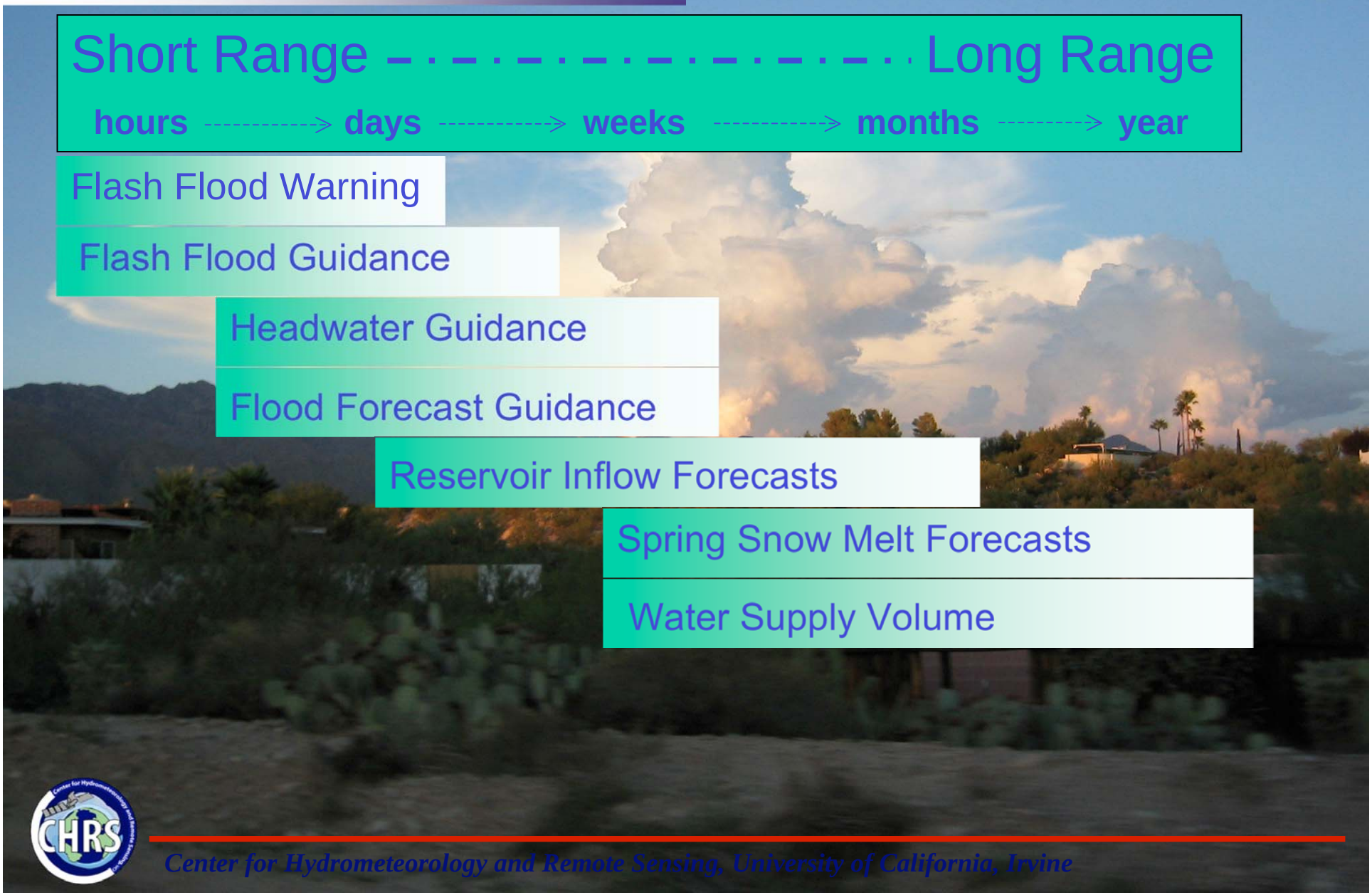



**Central Arizona Project Aqueduct**

SAHRA

# *Required Hydrometeorologic Predictions*



# Spatial Resolution Issues

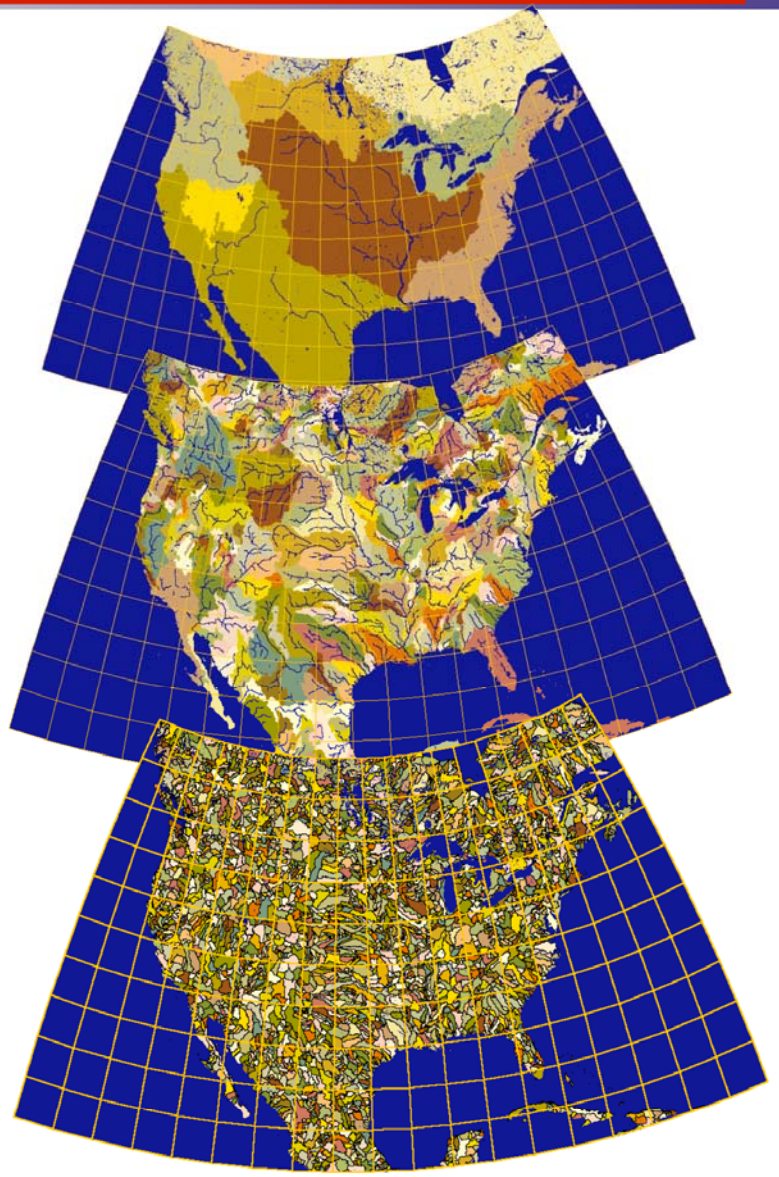
***Continental Scale:***

***Focus of modelers***

***Different Scales***
***Different Issues***
***Different Stakeholders***

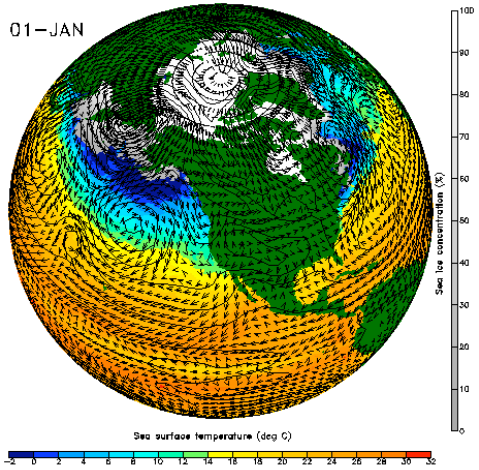
***Watershed Scale:***

***Where hydrology happens***
***Where stakeholders exist***



# *From Weather* → *to Hydrology*

## *NWP*




***Days to weeks***

***Rainfall Runoff Models***

***Advanced Hydrologic Prediction***

# From Climate → to Hydrology

**GCM**

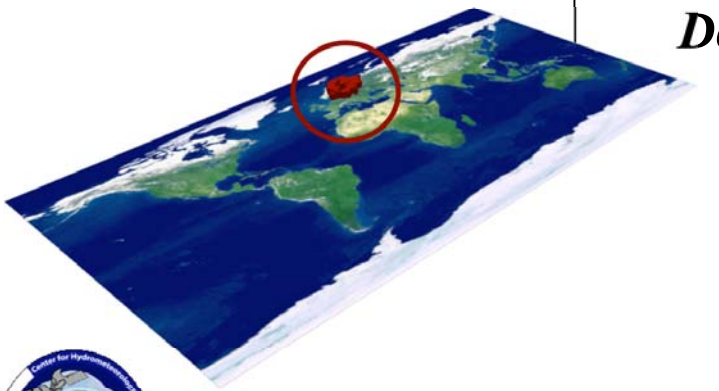
***Seasonal to Interannual***

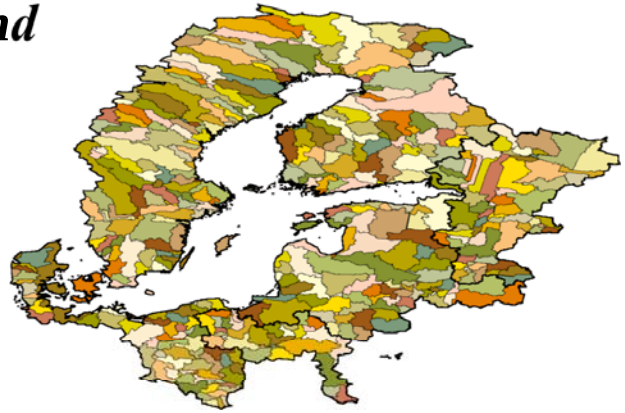
***Advanced Hydrologic Prediction***

***Statistical Estimates***

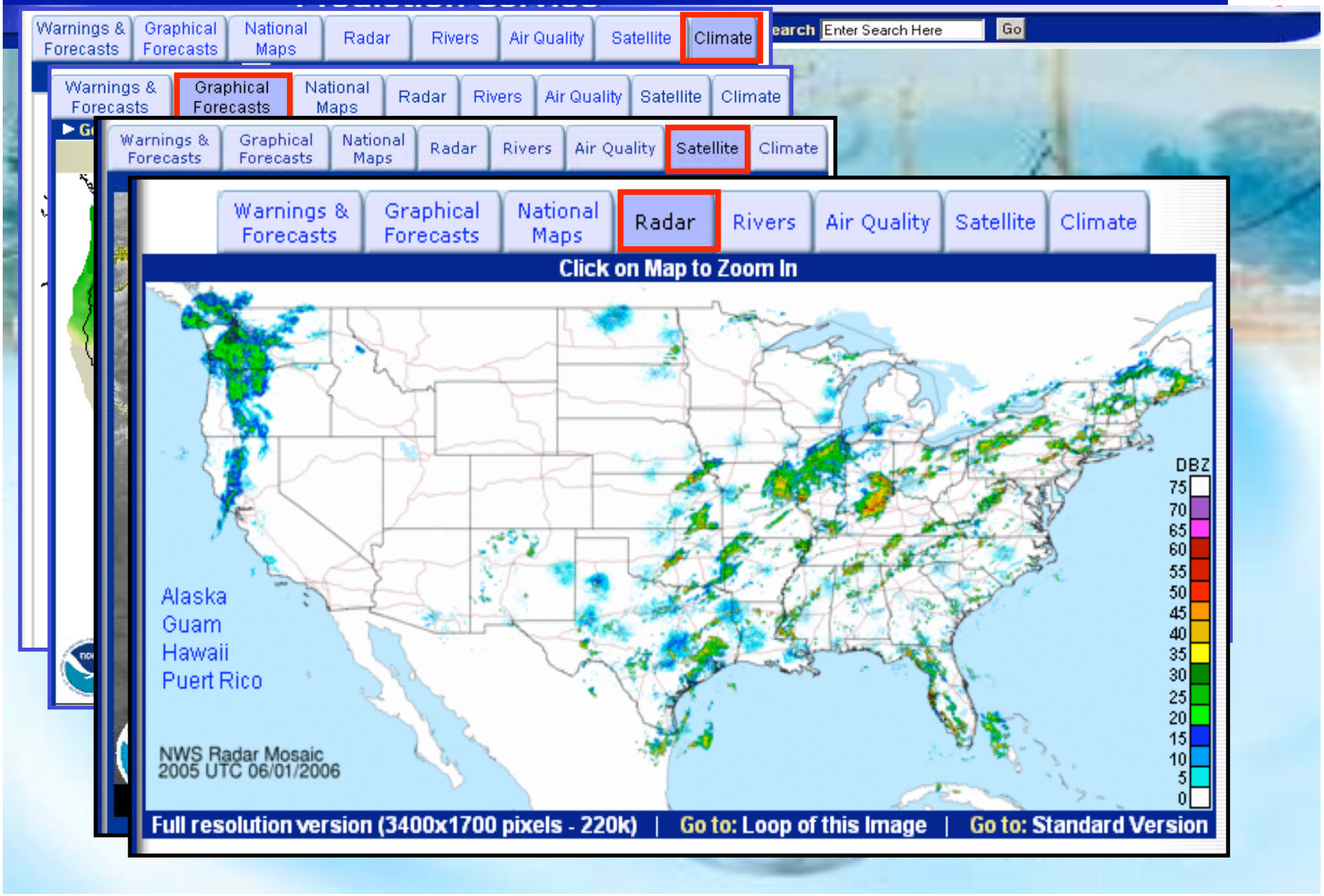
***Statistical Estimates***

***Decadal and Beyond***

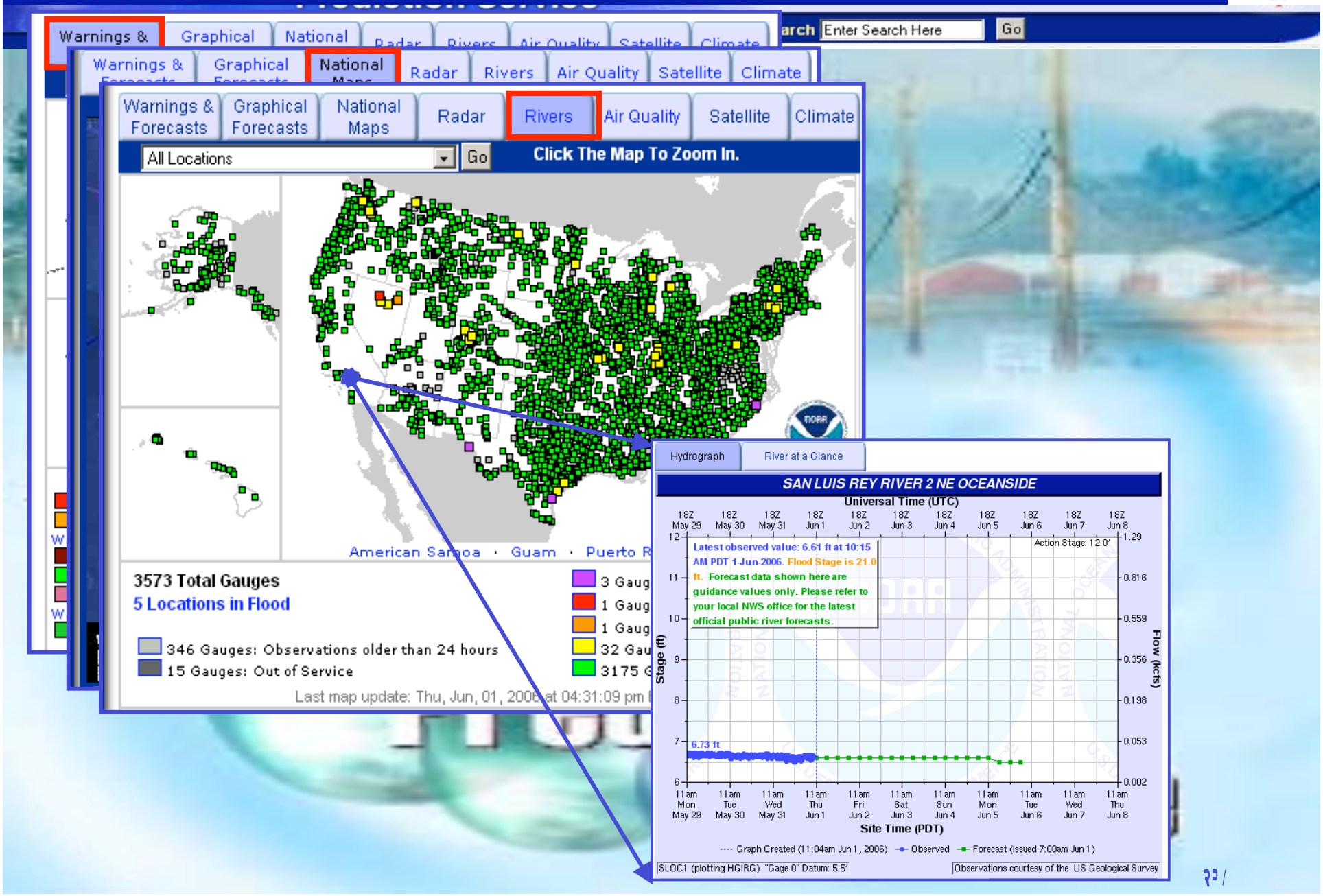




# *Advanced Hydrologic Prediction System (AHPS)*

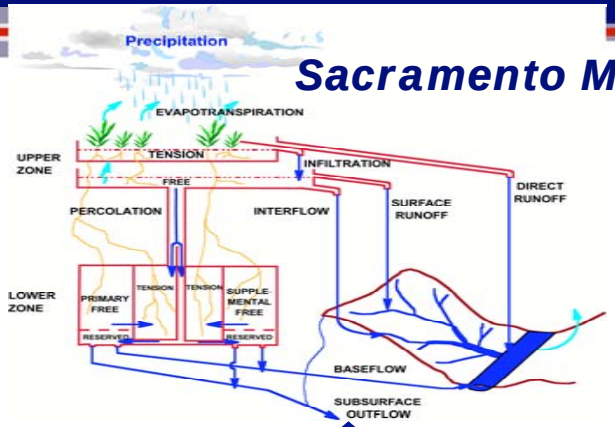


# Advanced Hydrologic Prediction System (AHPS)



# Hydrologic Models of Different Complexity

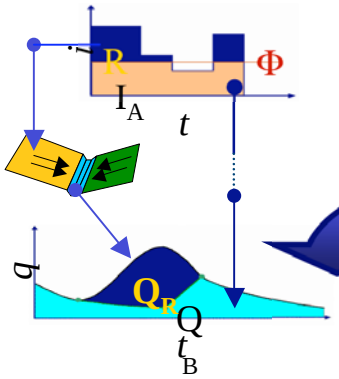
## Sacramento Model



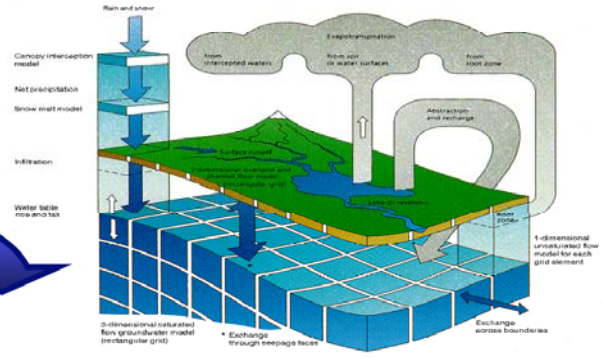

## API

Φ Index partitioning
Overland routing

Sum up flow components

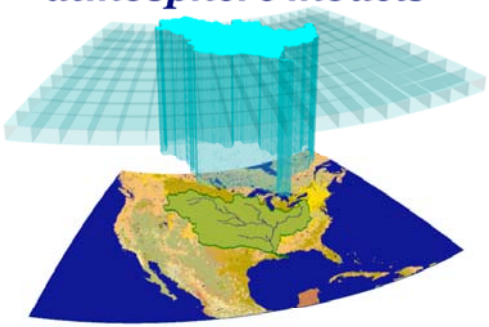



## Mike SHE Model

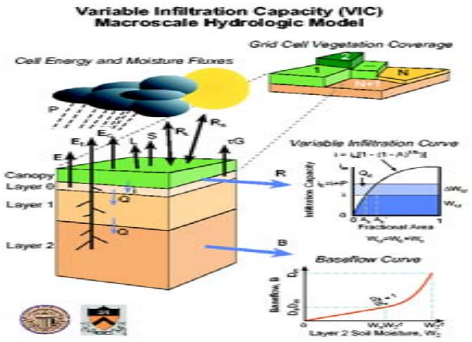


## Hydrologic Models

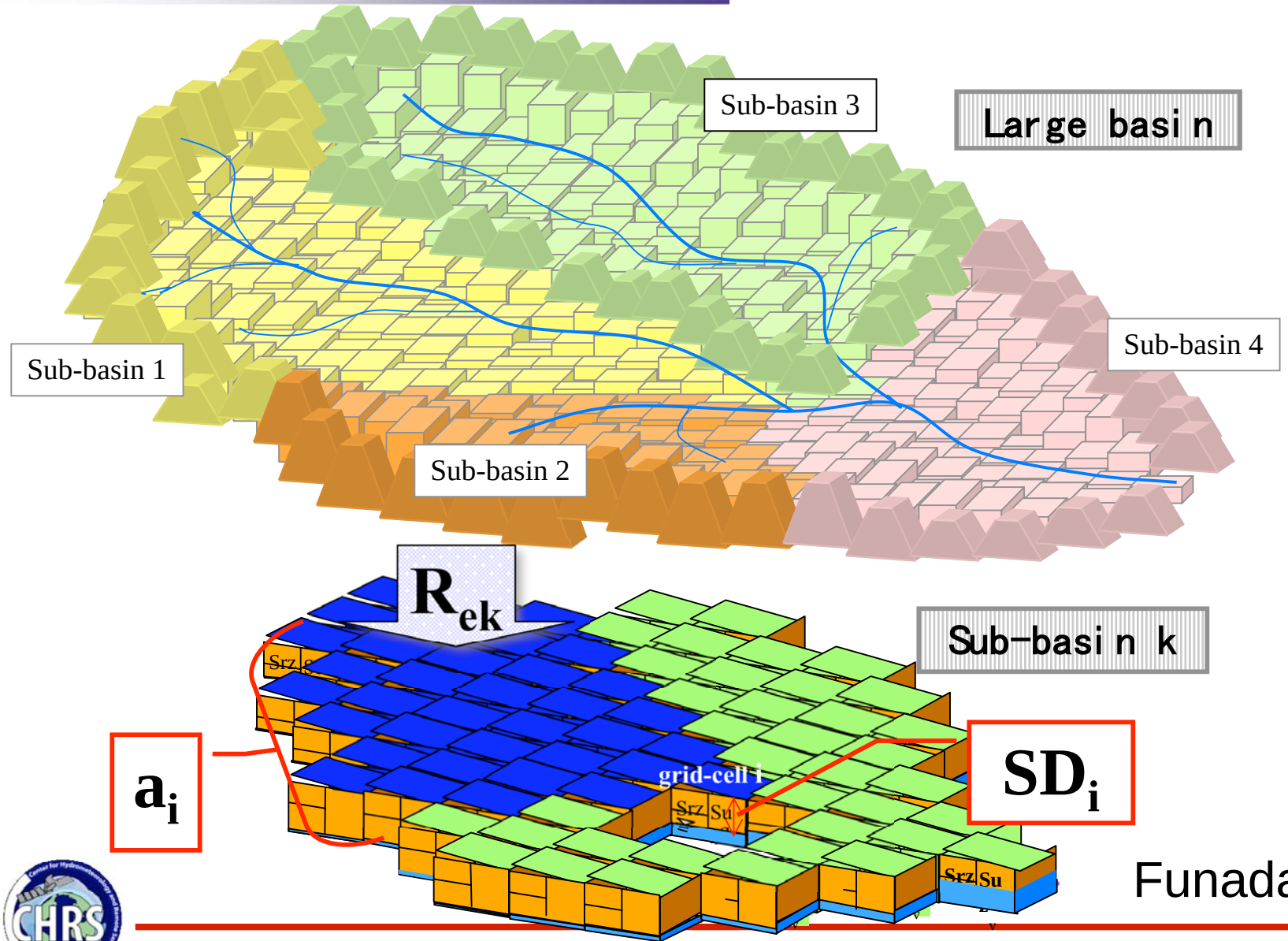
## Mesoscale coupled land-atmosphere models




## VIC Model



# An Example of Distributed Hydrologic Models




Funada, 2004

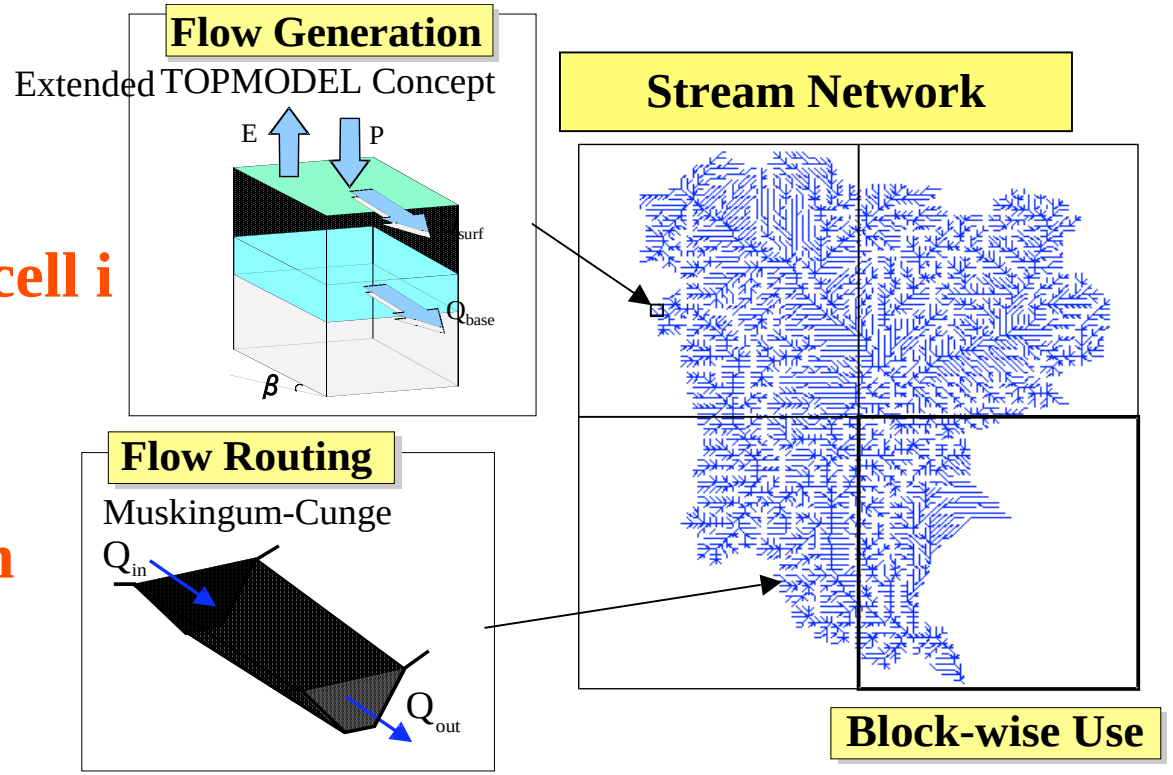
# *Example of Distributed Model*

*** Both Overland Flow and Base Flow are generated at each grid-cell,**

*** Flow routing over all the flow segments.**

**At each grid-cell i**

**For all stream segments**

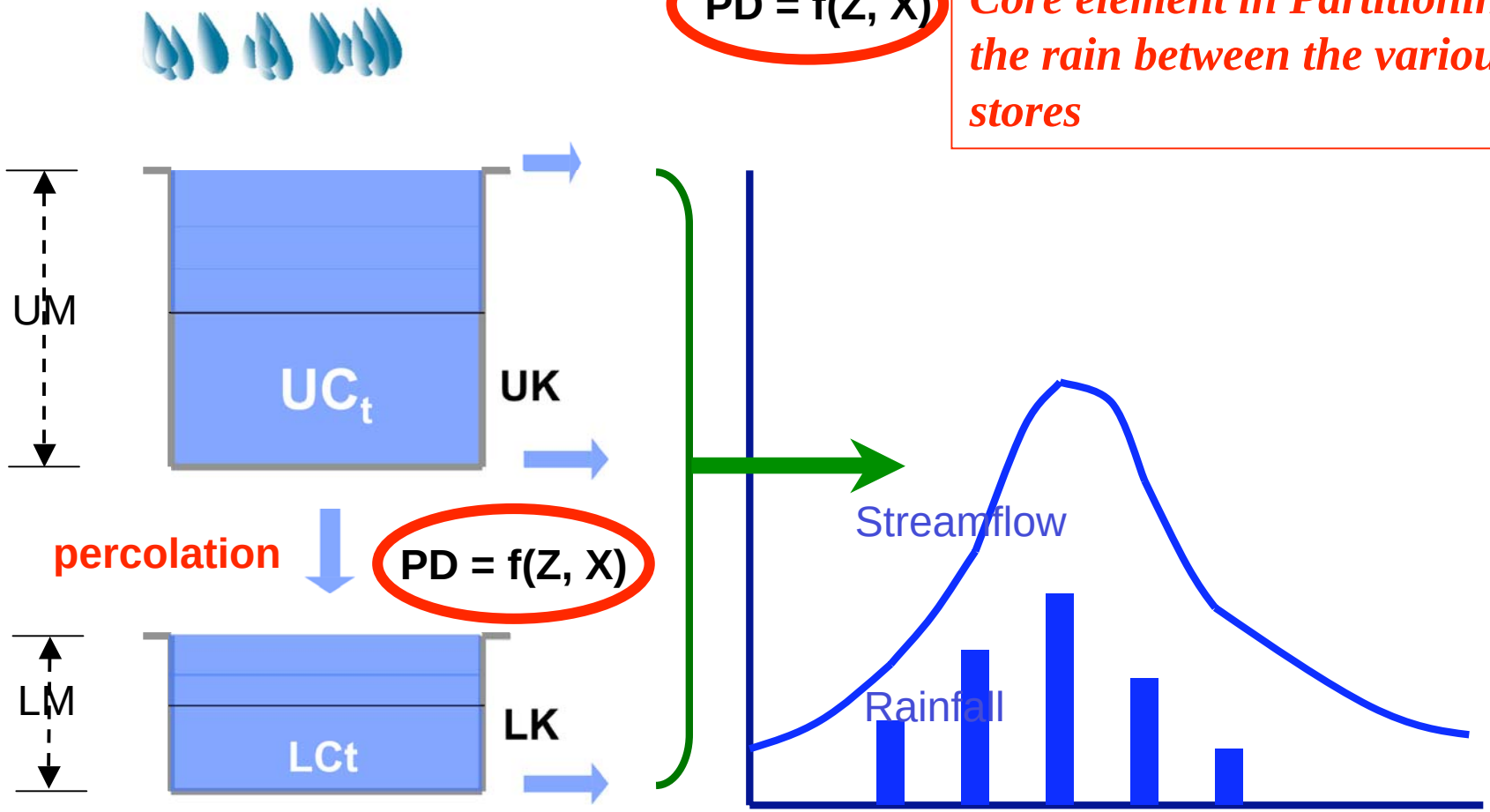



*(Takeuchi, Ao et al., 1999)*

# *The Weather Service R-R Model ( NWS-SRFS)*

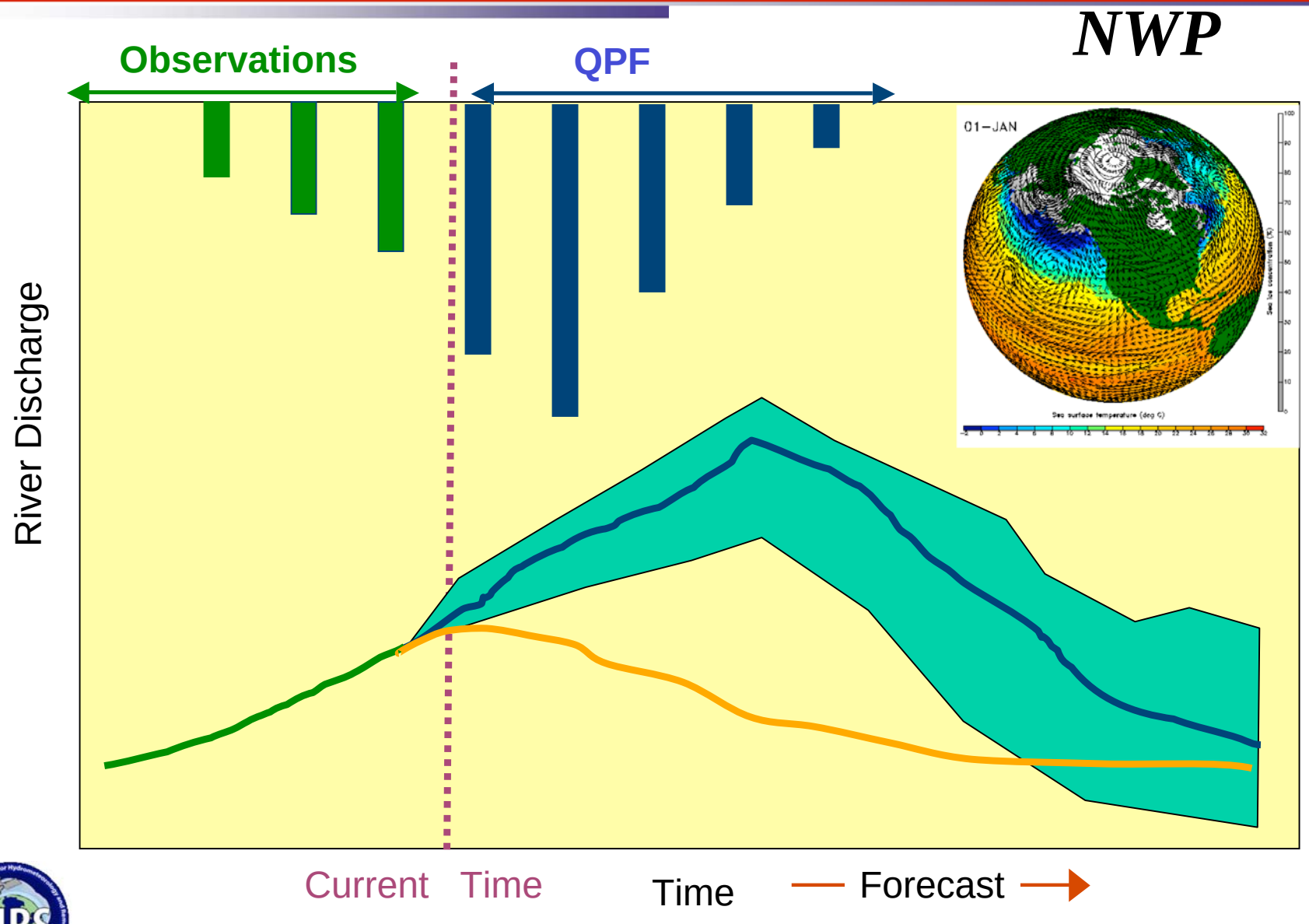
PD = f(Z, X)

*Percolation Process is the Core element in Partitioning the rain between the various stores*

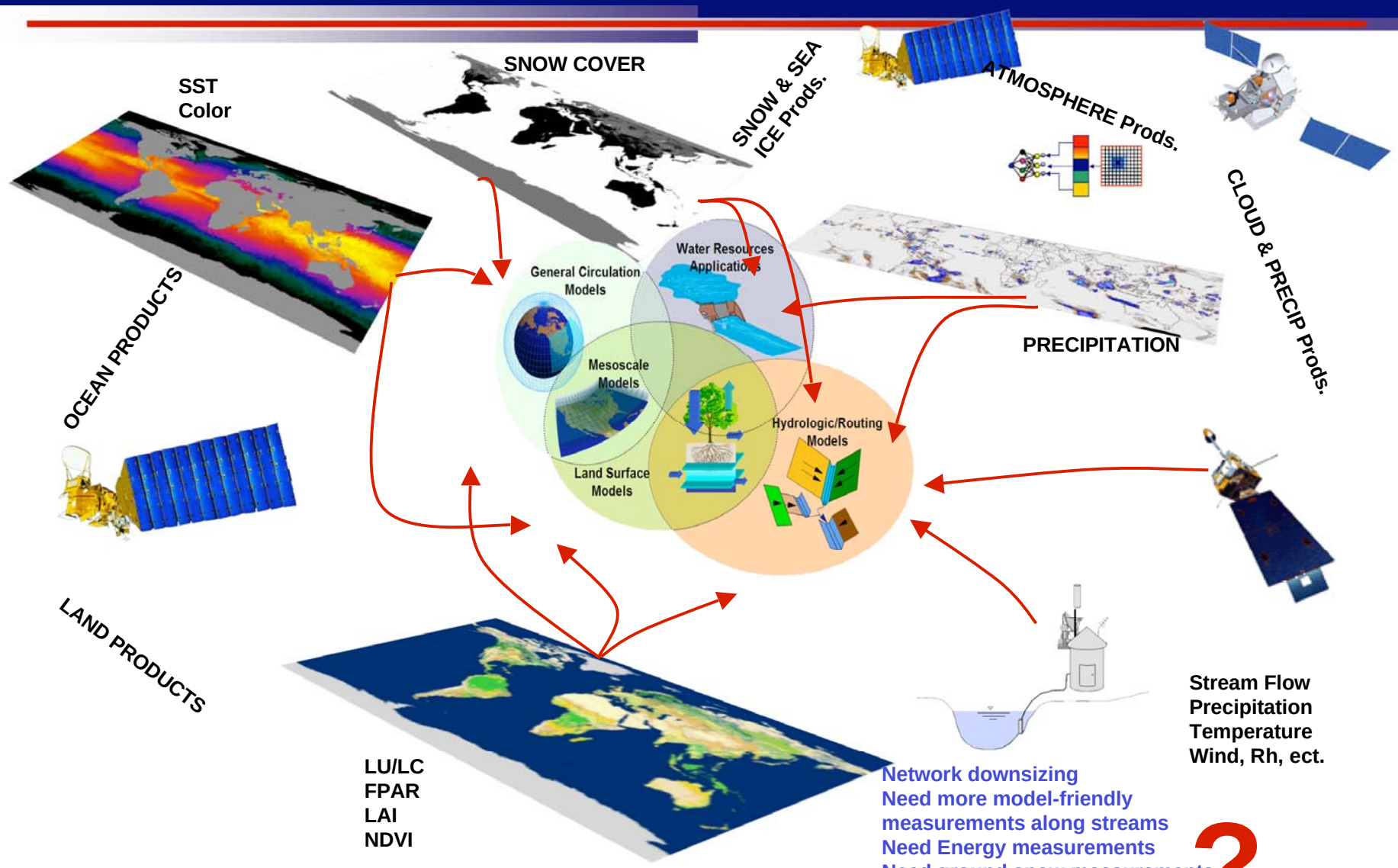



*Most Important Requirements: State Variables and Precipitation*

# Need to Extend the Forecast Lead time



# *Depending on the model choice, different info. needed*



# *Most Important*

***Precipitation*** ***is one of the***

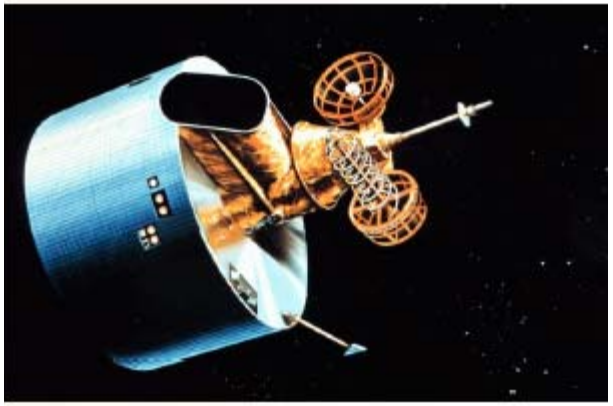
***KEY***

***hydrologic Challenges***

# *Precipitation Observations: Which to trust??*

Rain Gauges

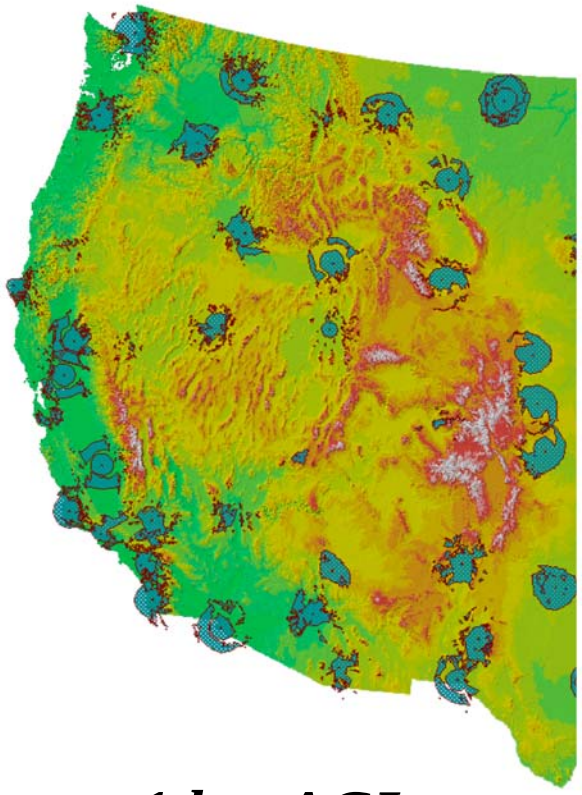
WSR-88D Radar



Satellite

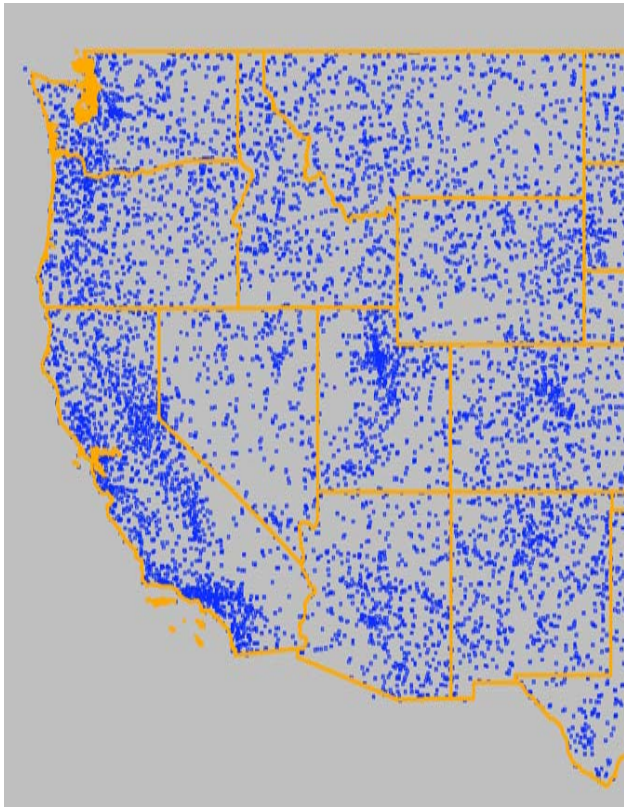
*Sources: R. Fulton, D.-J. Seo. and J. Breidenbach, AMS Short-Course on QPE/QPF, 2002*

# *Coverage of the WSR-88D and gauge networks*



***1 km AGL***

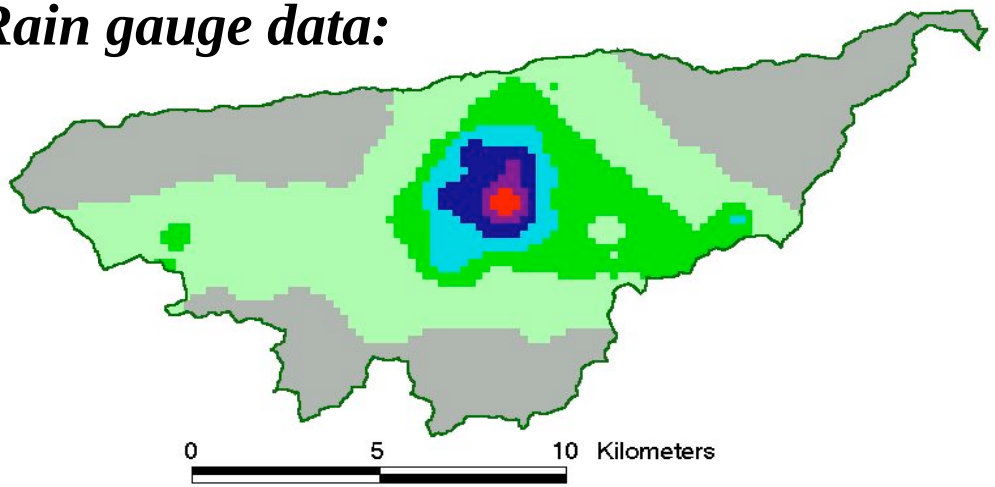
*Maddox, et al., 2002*



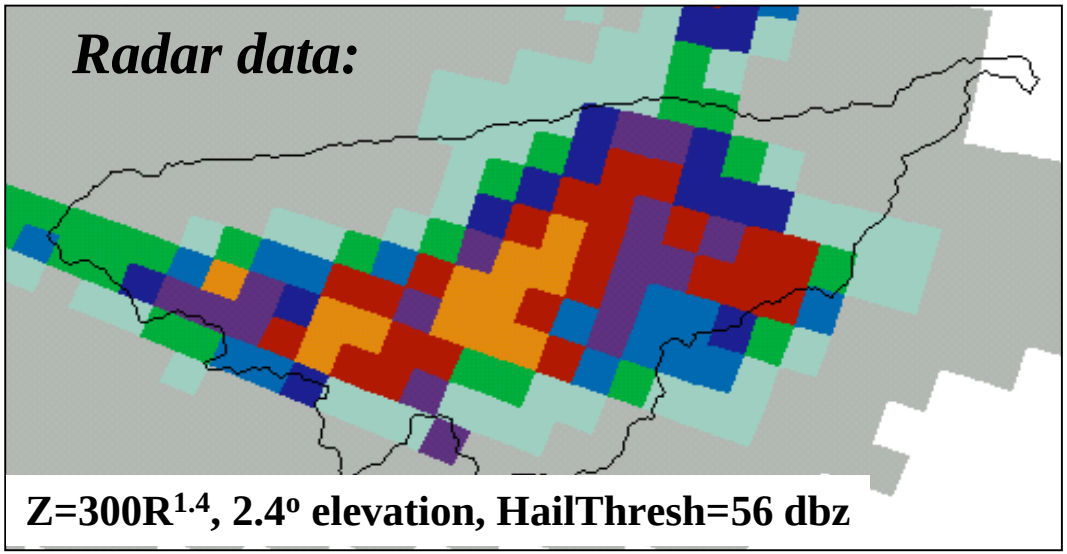
***Daily precipitation gages (1 station per 600 km^2 for Colorado River basin) hourly coverage even more sparse***

# *Radar-Gauge Comparison (Walnut Gulch, AZ)*

***Rain gauge data:***



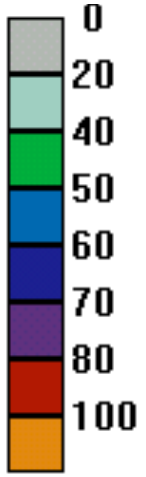

***Radar data:***



**Z=300R$^{1.4}$, 2.4$^{o}$ elevation, HailThresh=56 dbz**

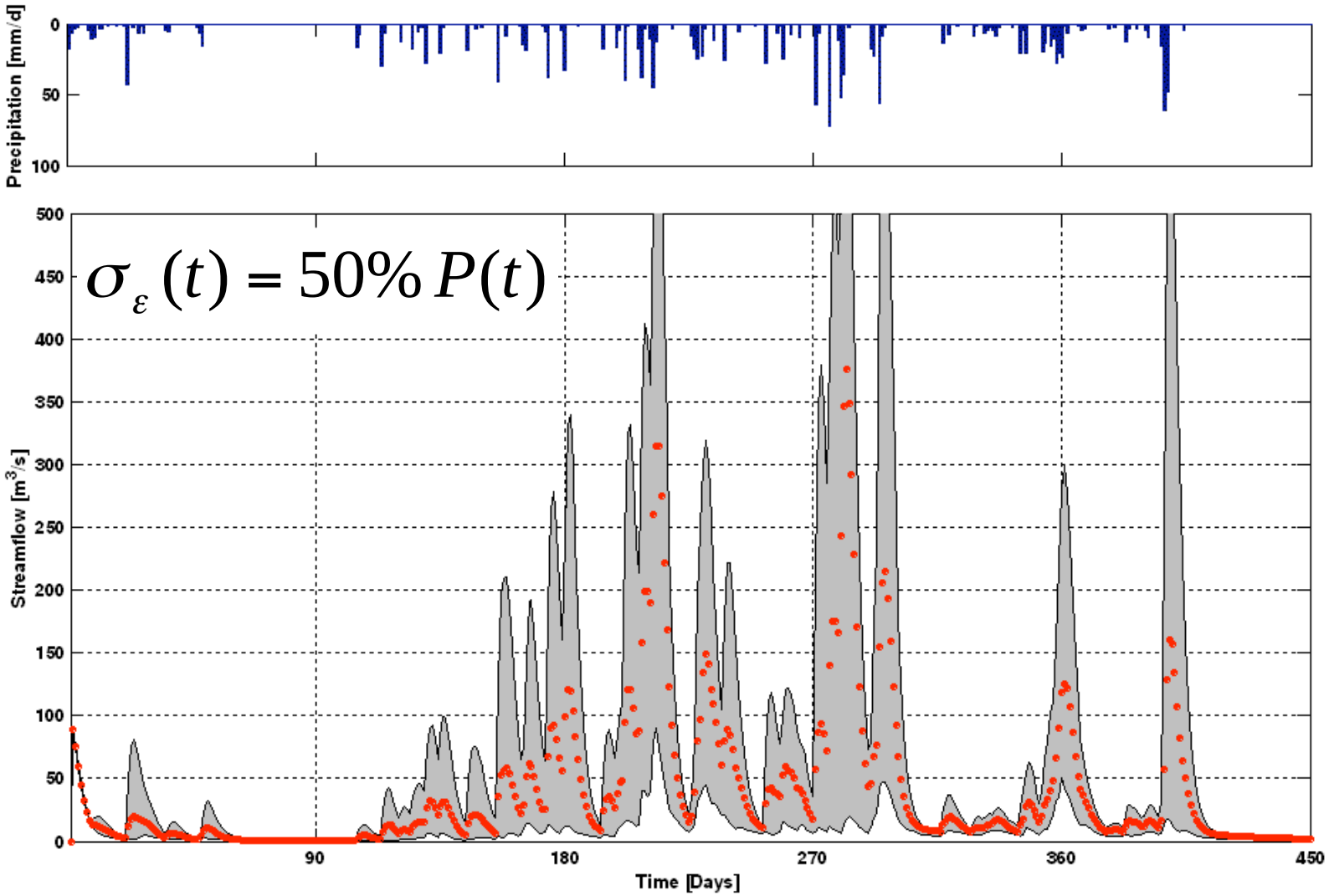
***Precipitation event: Aug. 11, 2000***

*Storm depth (mm)*

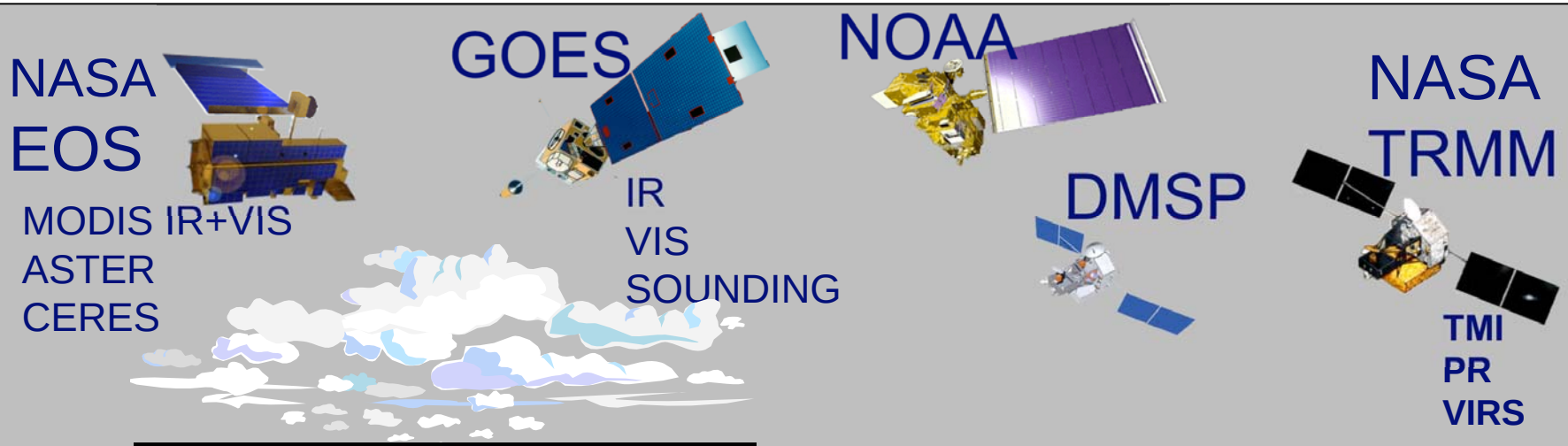


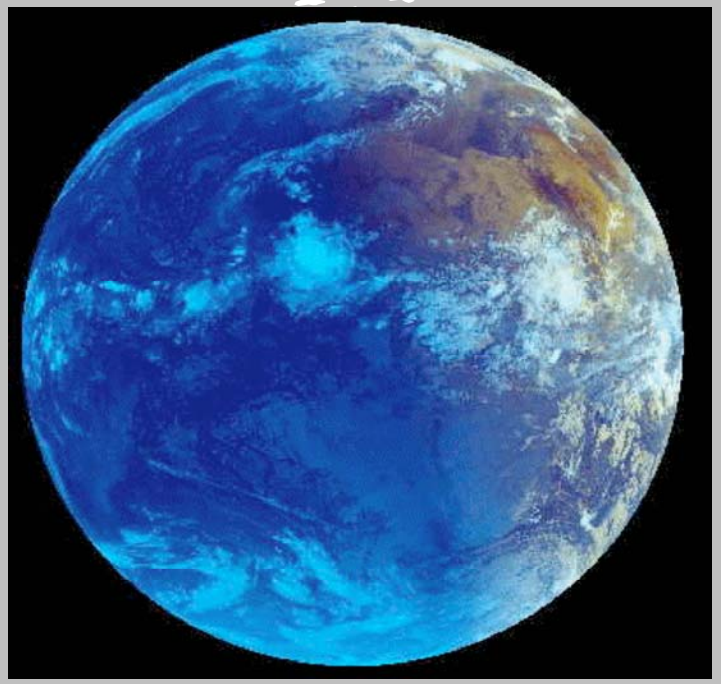

***70% overestimation by the radar!***

# *Streamflow Simulation vs. Precipitation Uncertainty:*



# *Satellite-based Observations will be critical*



**Observations from space:**

**Near-continuous, global coverage,**

**Big Challenge:**

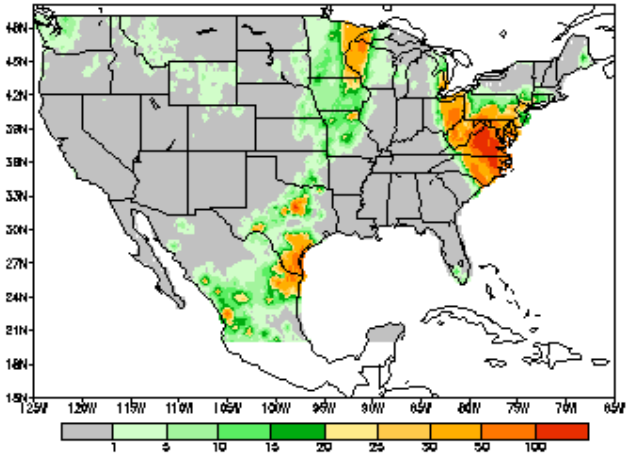
**Verification of how good they are??**

# Positive Steps: Daily Precipitation Validation (US)

**http://www.cpc.ncep.noaa.gov/products/janowiak/us_web.html**

13Z 19Sep2003 thru 12Z 19Sep2003
Data on 0.25 deg grid (UNITS are mm/day)

CPC real-time Gauge Analysis



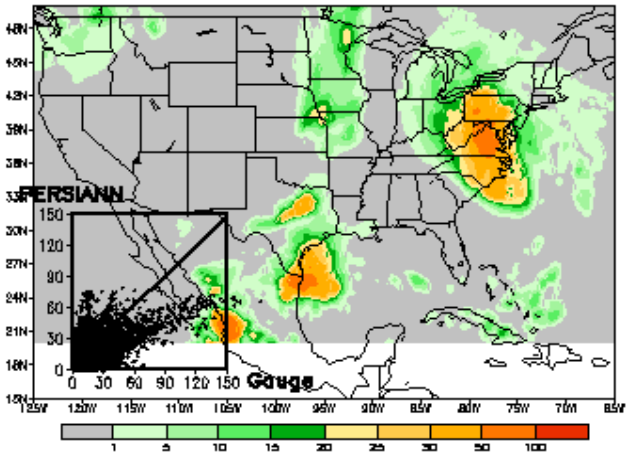
| | (G) gauge | (S) PERSIANN | (R) radar |
|---|---|---|---|
| Number of points: | 13828. | 13828. | 13828. |
| # points w/rain: | 4249. | 4665. | 2971. |
| Mean rain rate: | 5.56 | 4.25 | 3.13 |
| Cond. rain rate: | 17.82 | 12.47 | 14.46 |
| Max. rain rate: | 181.99 | 79.07 | 131.45 |

| | G-S | G-R | R-S |
|---|---|---|---|
| Correlation: | 0.827 | 0.726 | 0.606 |
| Mean Absolute Error: | 3.63 | 3.42 | 3.35 |
| RMSE (mm/day): | 9.44 | 11.23 | 8.66 |
| RMSE (normalized): | 1.70 | 2.02 | 2.77 |
| Probability of Detection: | 0.746 | 0.654 | 0.855 |
| False Alarm Ratio: | 0.321 | 0.065 | 0.455 |
| Bias Ratio (rain:no rain): | 1.098 | 0.699 | 1.570 |
| Heidke Skill Score: | 0.574 | 0.692 | 0.546 |
| Hanssen-Kuipers Score: | 0.589 | 0.634 | 0.660 |
| Equitable Threat Score: | 0.402 | 0.528 | 0.376 |

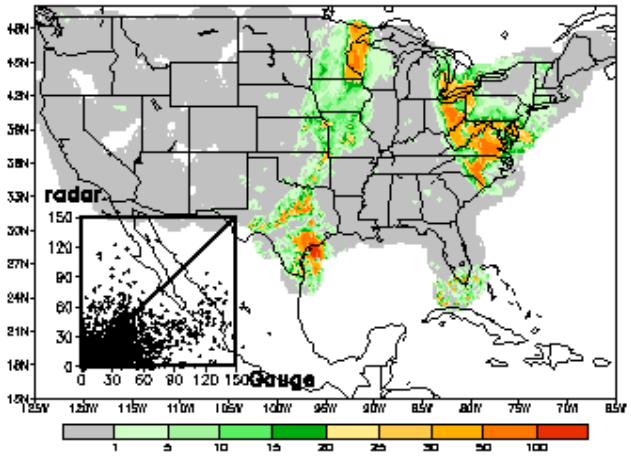
| gauge \ PERSIANN | < 1 | ≥ 1 |
|---|---|---|
| < 1 | 8082. | 1497. |
| ≥ 1 | 1081. | 3168. |

| gauge \ radar | < 1 | ≥ 1 |
|---|---|---|
| < 1 | 9386. | 193. |
| ≥ 1 | 1471. | 2778. |

PERSIANN



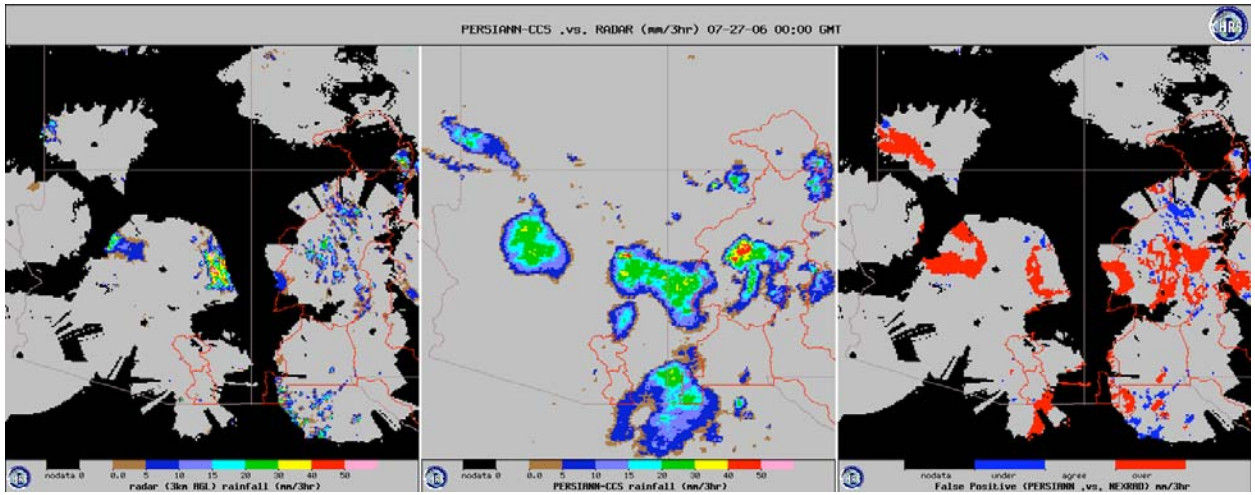

Radar



# *Verification: A Painful but Critical Requirement*

**In summer of 2006, Southwestern U.S. experienced a series of record flash floods due to a "strong" North American Monsoon.**

**This demo shows the potential of using satellite rainfall estimates to improve flood warning.**




**Radar beams (3-km above ground level) are blocked by mountains in SW.**

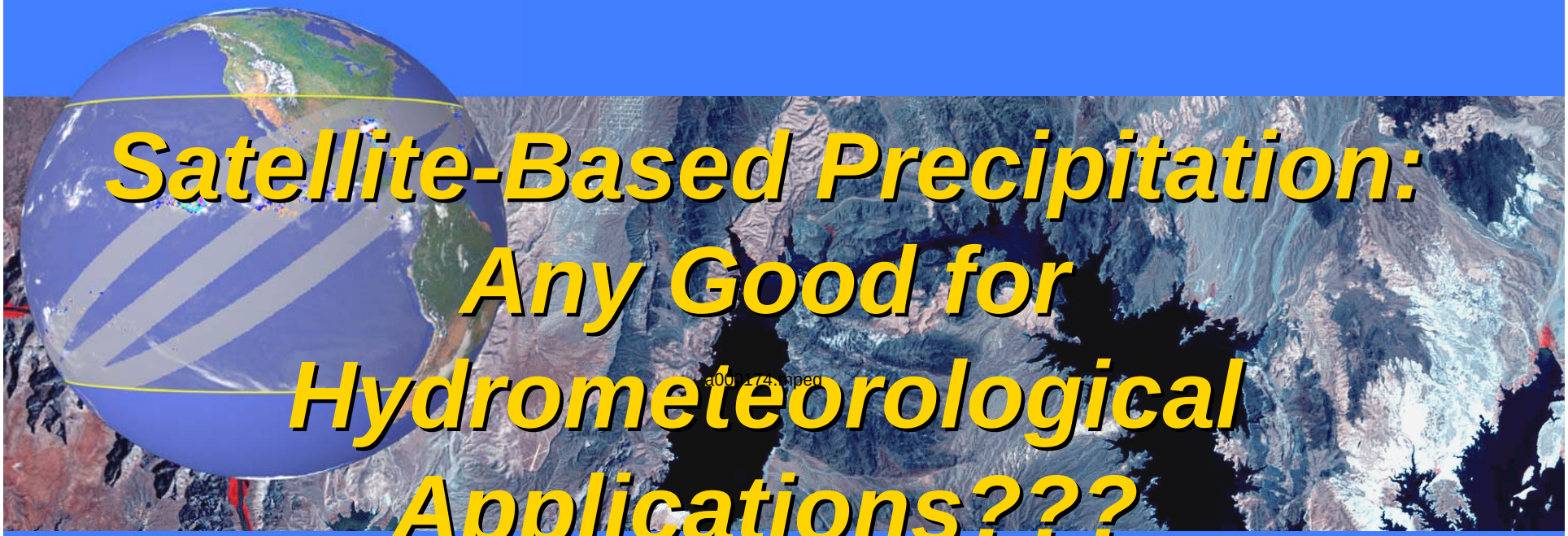
**Strong convection starts over mountains where radar coverage is poor. PERSIANN's continuous monitoring of storm systems, provides useful information for early warning.**

**Differences between PERSIANN and radar images exist.**

**Red: PERSIANN showed Rain but Radar showed No Rain**

**Blue: PERSIANN No Rain vs. Radar Rain**

*X. Gao, K. Hsu, B. Imam, et al., 2005*



# Satellite-Based Precipitation: Any Good for Hydrometeorological Applications???

# *Very Promising*

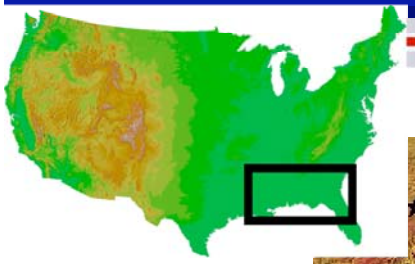
*Center for Hydrometeorology and Remote Sensing, University of California, Irvine*

# *Hydrologic Application: SMA-NWSRFS*

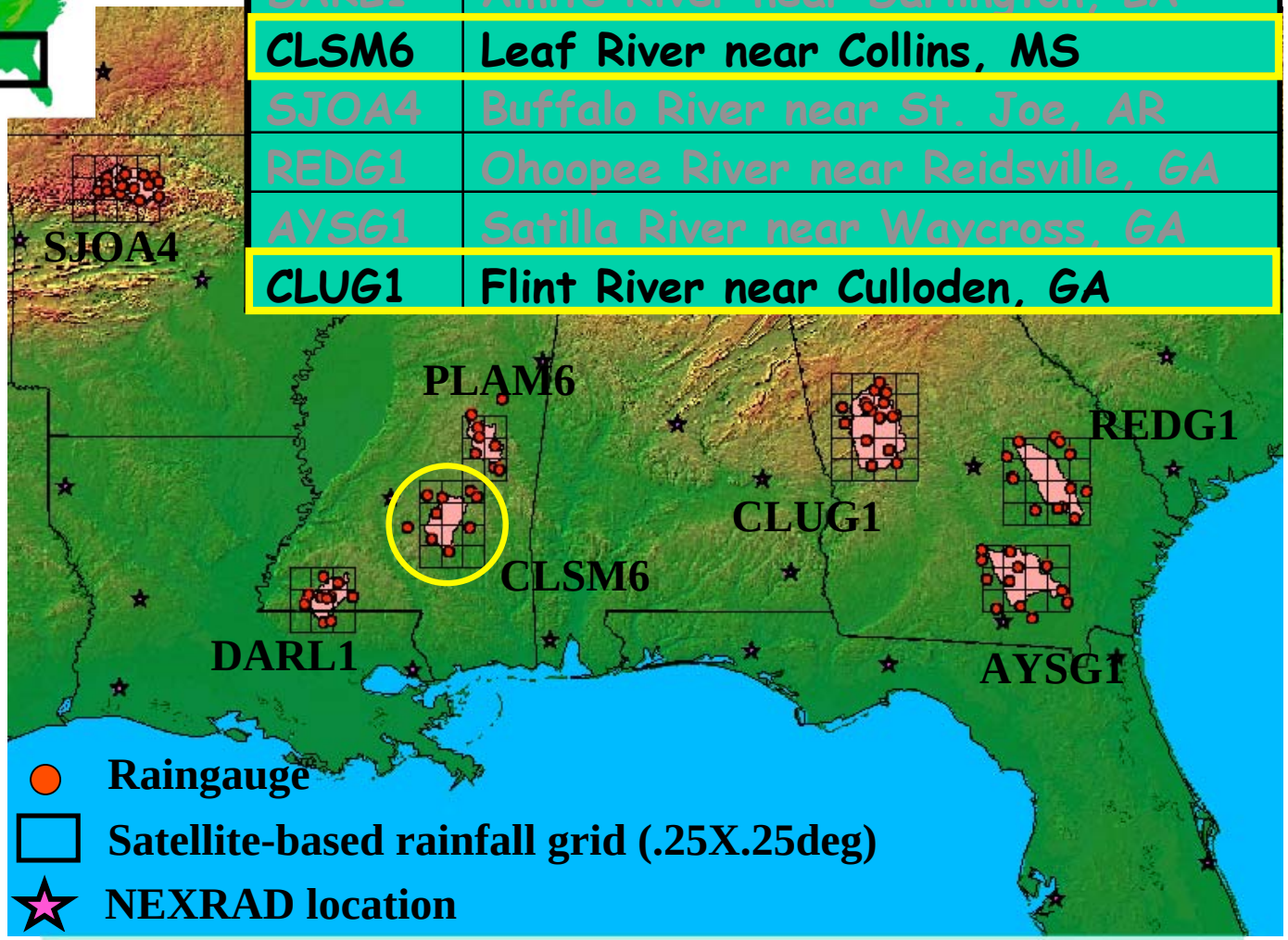



***Yilmaz etal. JHM 2005***

# Study Area

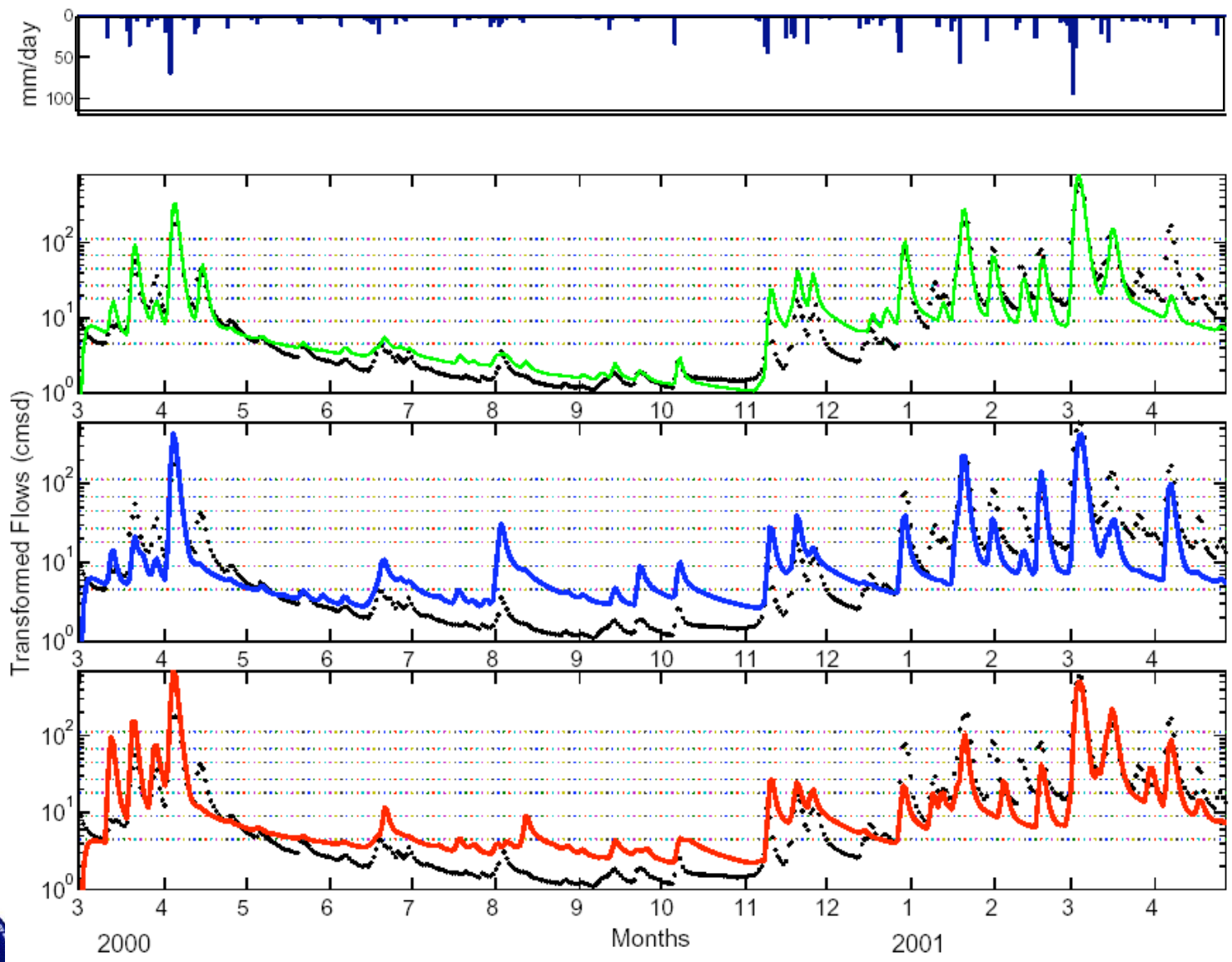


| | |
|---|---|
| PLAM6 | Pearl River near Burnside, MS |
| DARL1 | Amite River near Darlington, LA |
| **CLSM6** | **Leaf River near Collins, MS** |
| SJOA4 | Buffalo River near St. Joe, AR |
| REDG1 | Ohoopee River near Reidsville, GA |
| AYSG1 | Satilla River near Waycross, GA |
| **CLUG1** | **Flint River near Culloden, GA** |




Study time period : March 2000 – October 2003

# *Simulation using gauge, radar, and PERSIANN Estimates*




**RAINGAGE**

**Corr =0.95**
**RMS =23.9**
**BIAS =-1.32**

**RADAR**

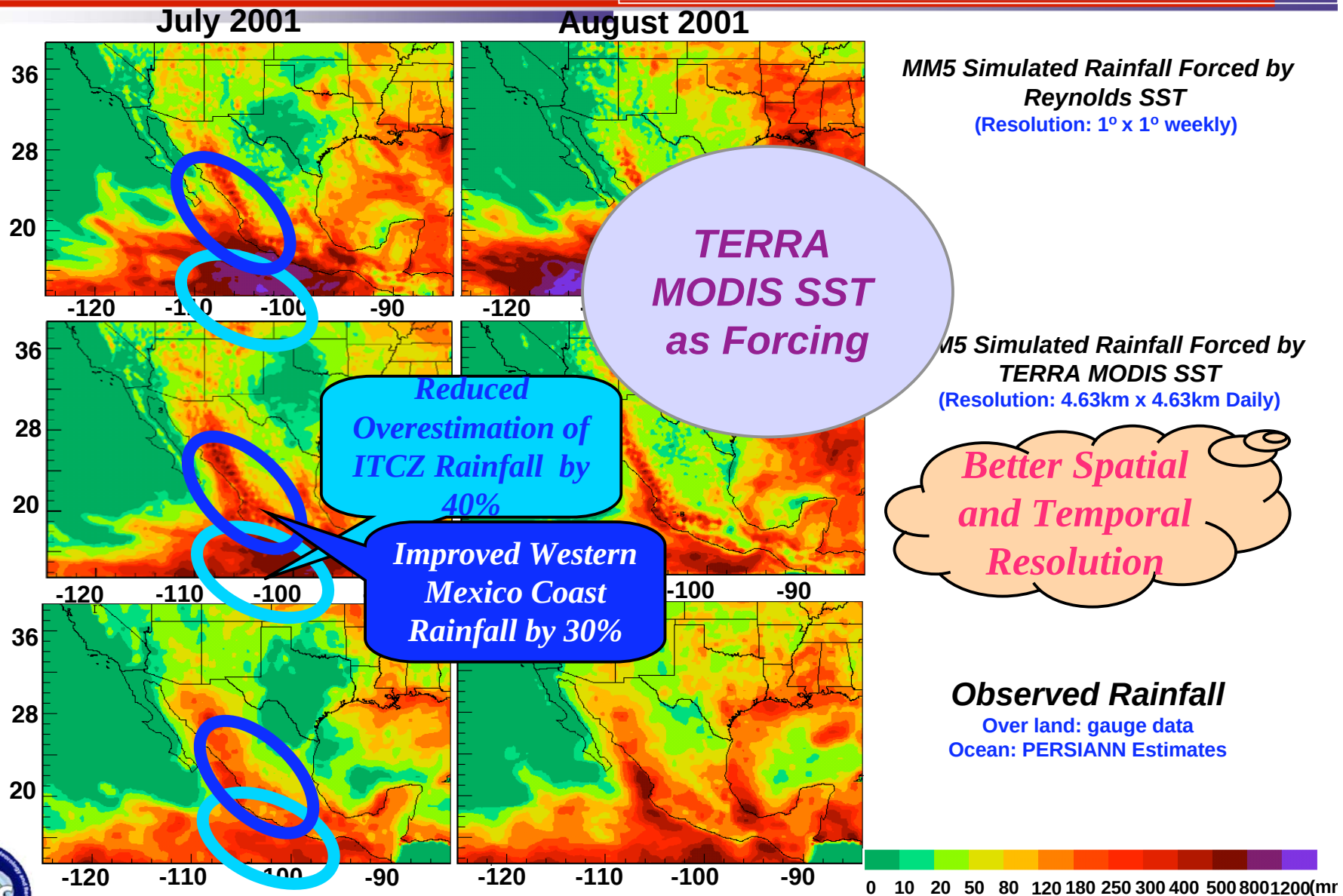
**Corr =0.92**
**RMS =28.8**
**BIAS =-6.74**

**PERSIANN**

**Corr =0.94**
**RMS =22.6**
**BIAS =-5.15**

# TERRA Satellite SST Improves North American Monsoon Rainfall Simulation

*Source: UC Irvine Research Group, Li et.al*




***MM5 Simulated Rainfall Forced by Reynolds SST***
**(Resolution: 1º x 1º weekly)**

***M5 Simulated Rainfall Forced by TERRA MODIS SST***
**(Resolution: 4.63km x 4.63km Daily)**

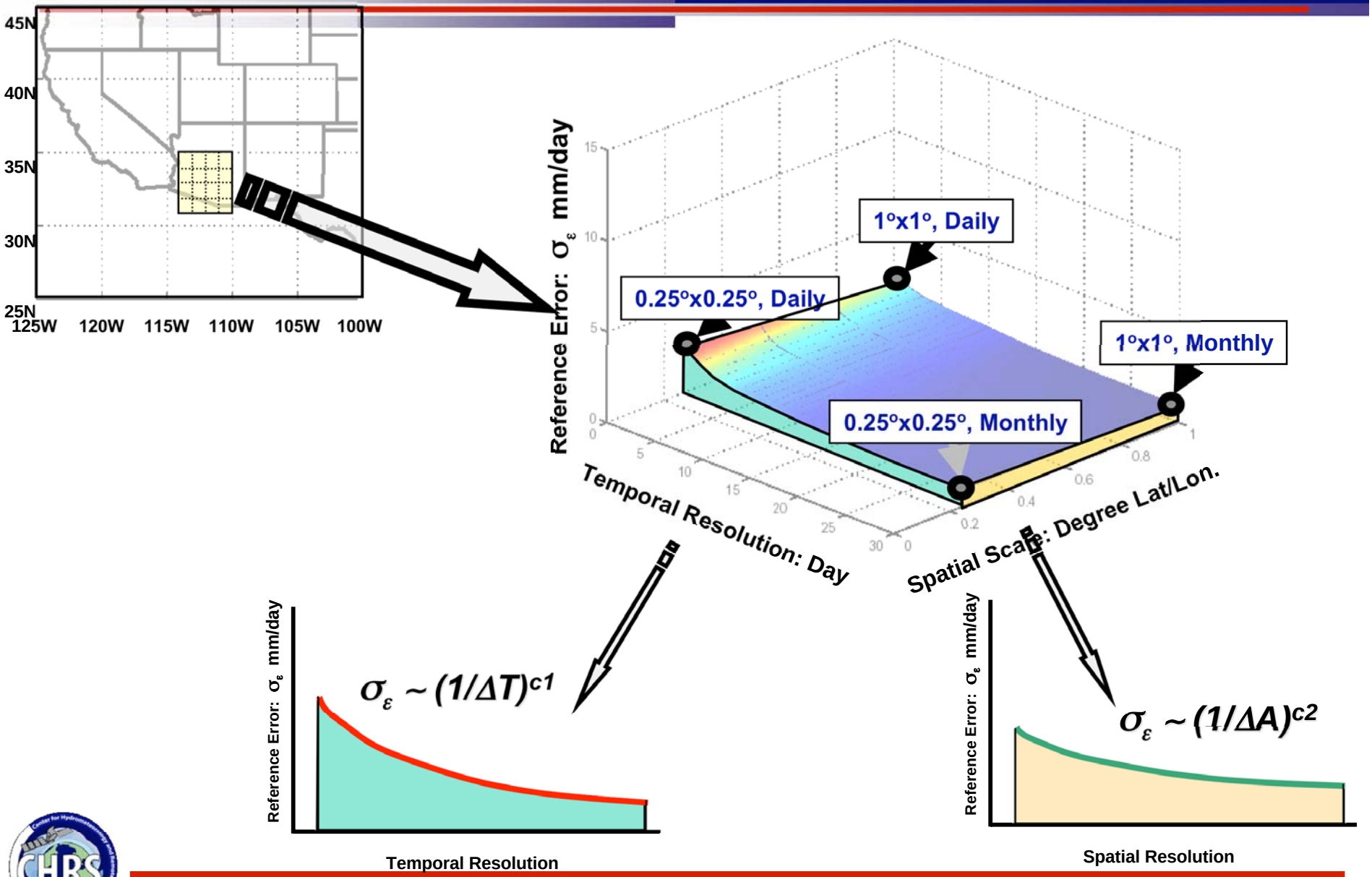
***Better Spatial and Temporal Resolution***

***Observed Rainfall***
**Over land: gauge data**
**Ocean: PERSIANN Estimates**

# *How best to Represent the Estimation Errors?*

- ***Uncertainty of Estimates***
  - ***Error Analysis***

# Spatial-Temporal Property of Reference Error

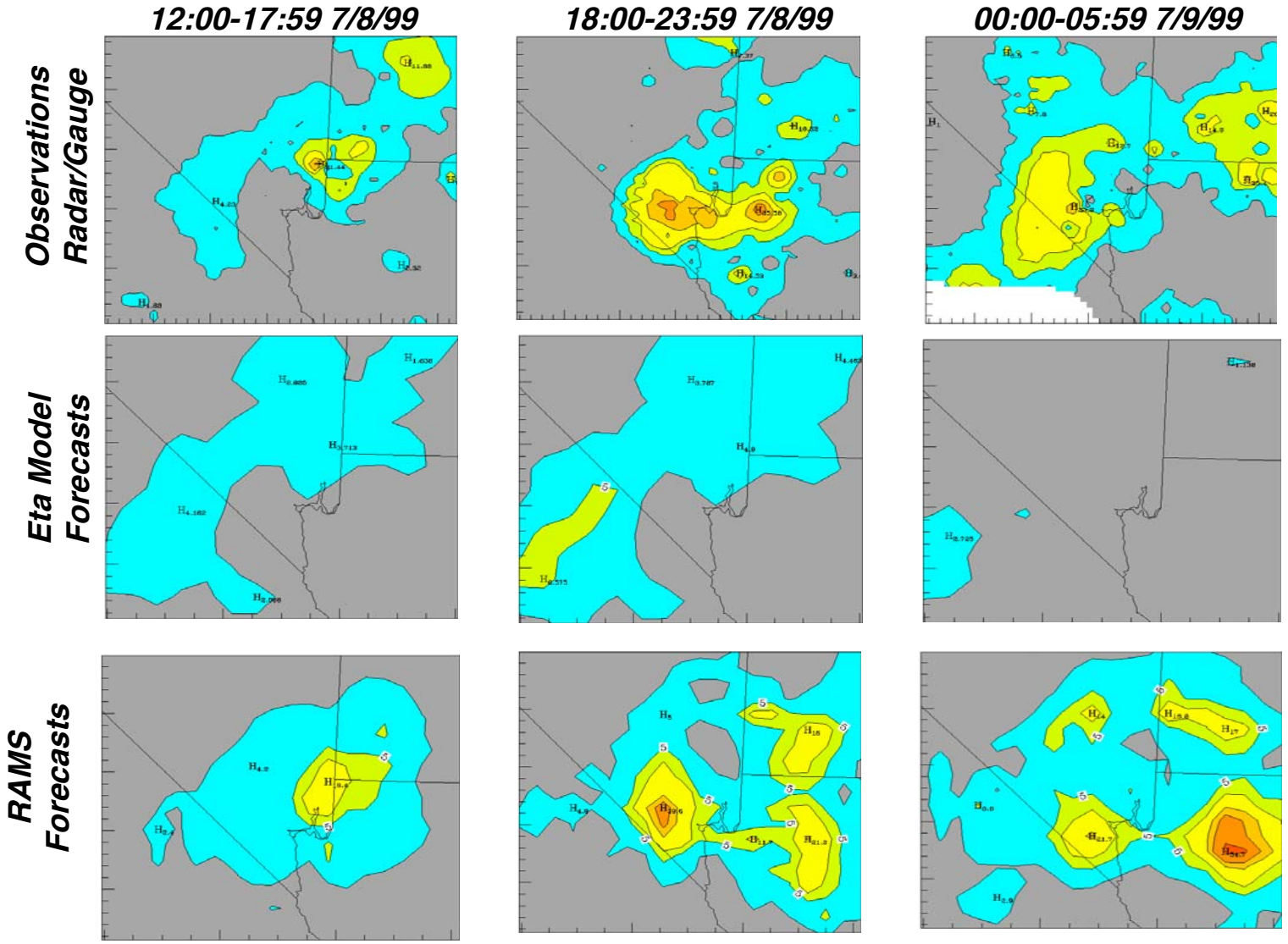


# *Acceptability of QPF in Practice*

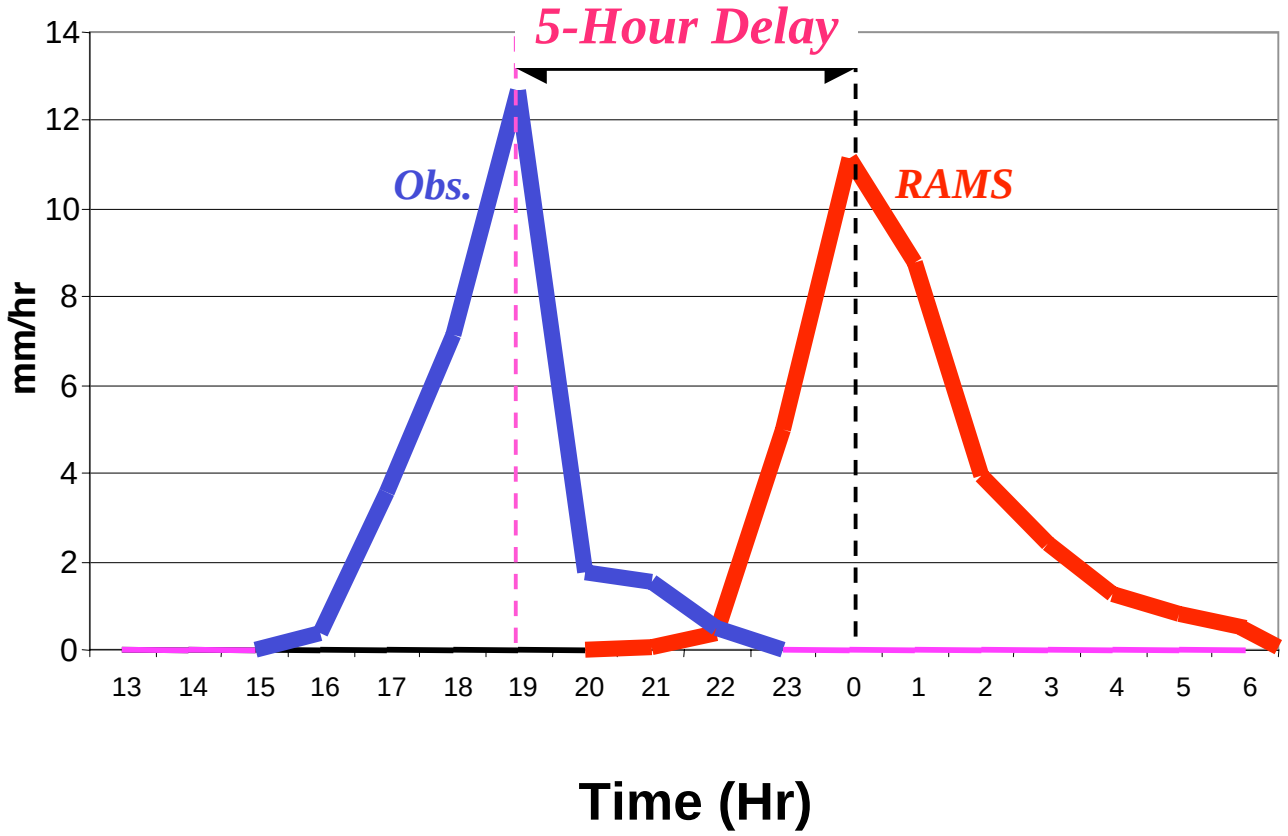
# *Some Recent Results!*

# Las Vegas Flood: July 8, 1999

# The Storm's Rainfall Measurements and Forecasts

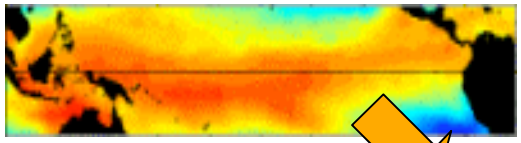


# Rainfall Time Series in Las Vegas Area



# "End-to-End" Prediction

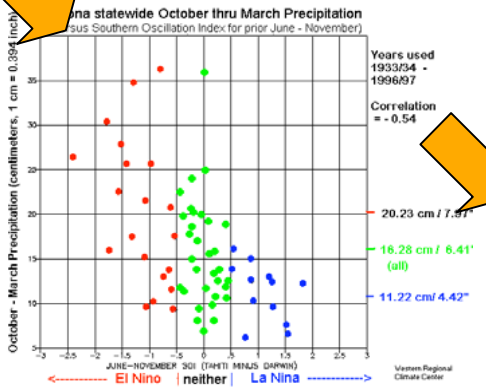
**From climate prediction**

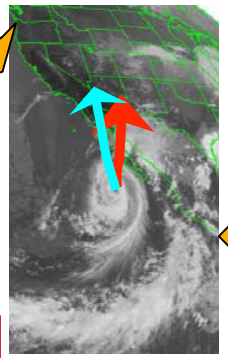


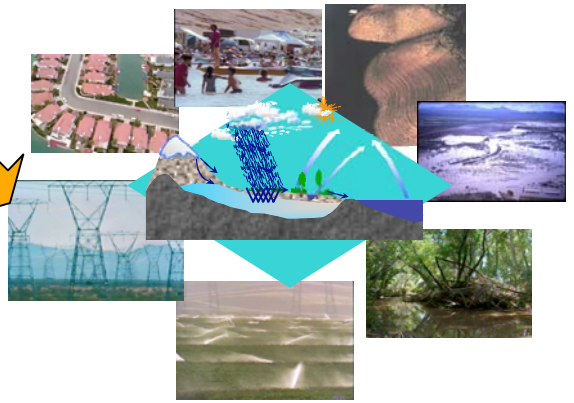
**To Weather predic: the actual event**

**Decisions**

**To impact on water resources**





**El Nino Prediction**

**Wetter than average winter Hurricane Nora**

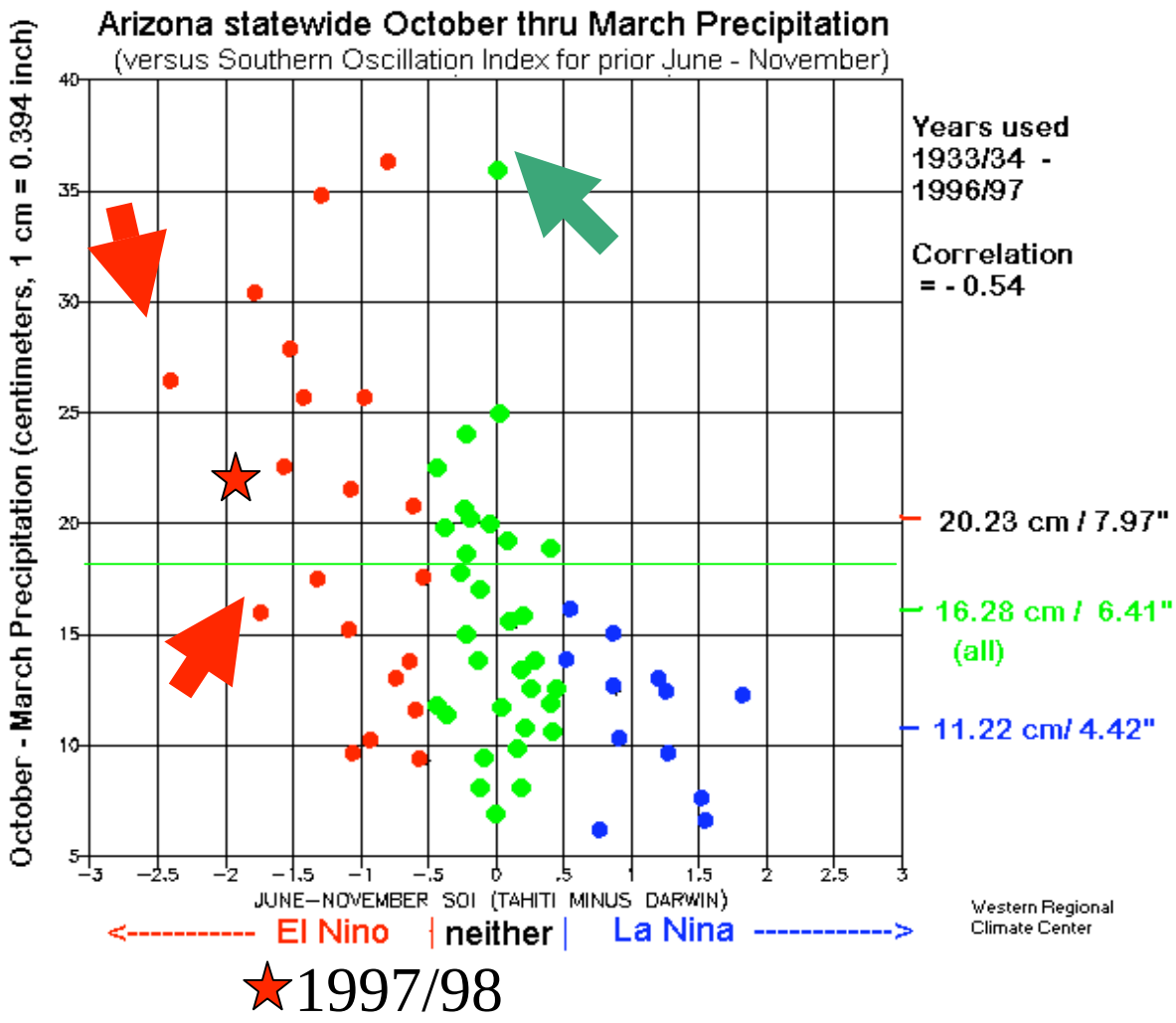
**Early Releases**

**Water Saved**

*Source: S. Sorooshian GEWEX-SSG*

# *El Nino Climate Signal In Western US*

Oct-Mar Rainfall

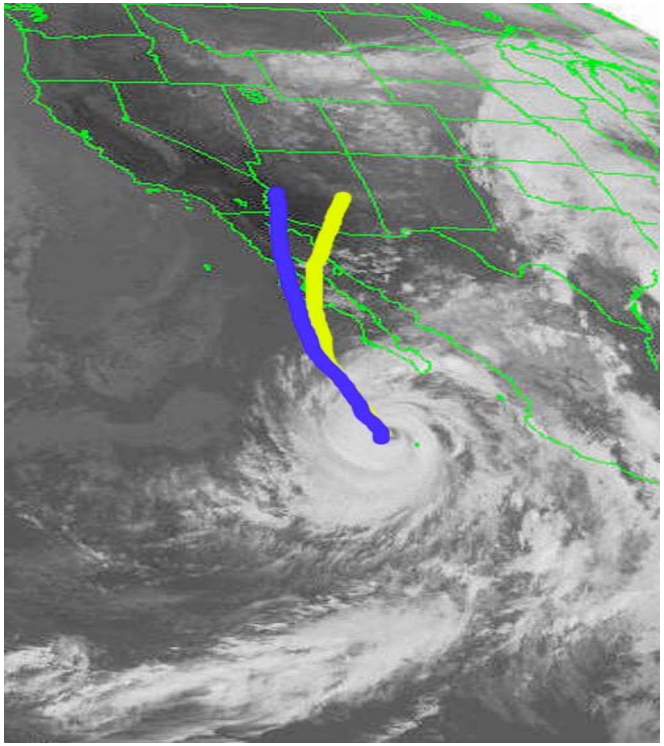



El Nino winters may be very wet.

Very wet winters are typically El Nino winters, but not always...

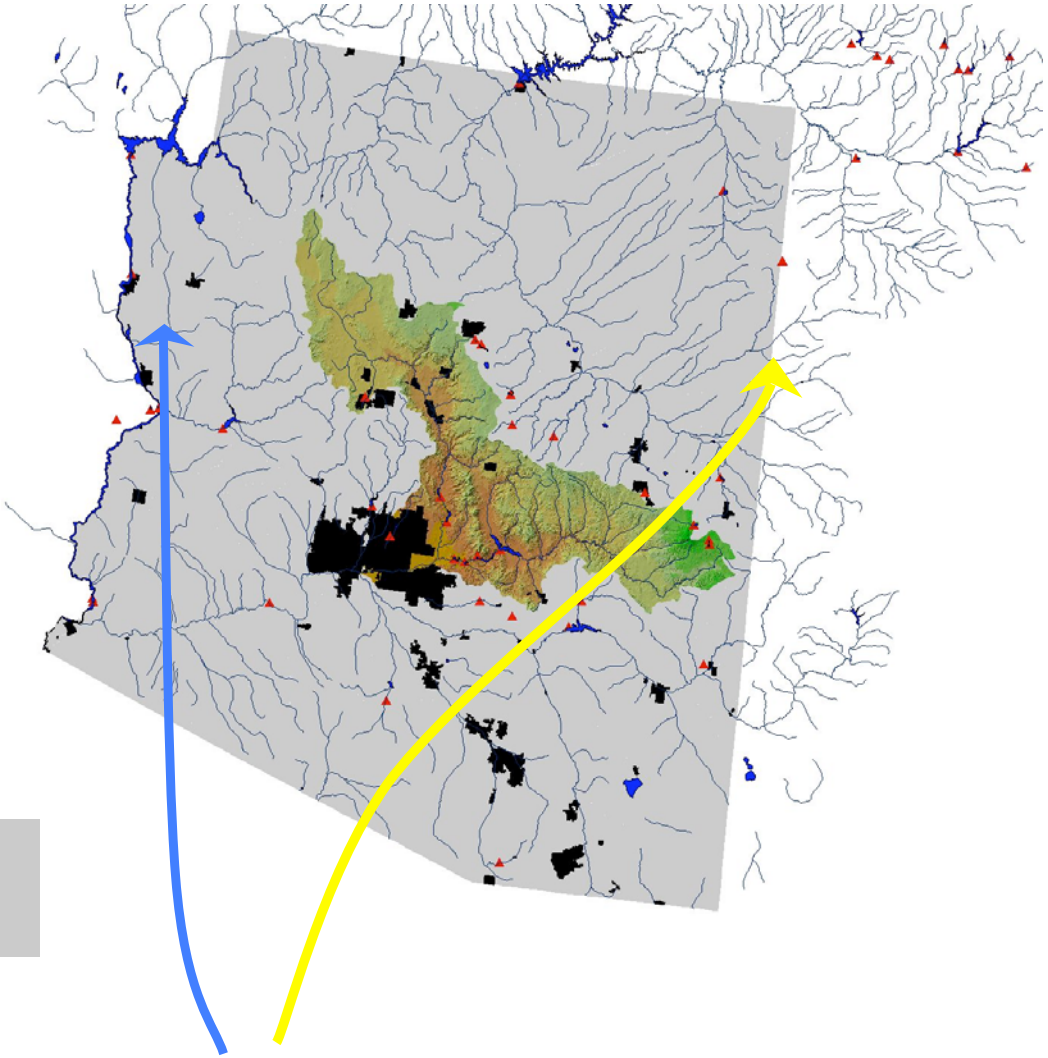
La Nina winters are typically dry, but reliably not wet.

# *Implication of Short-term Forecast Accuracy*



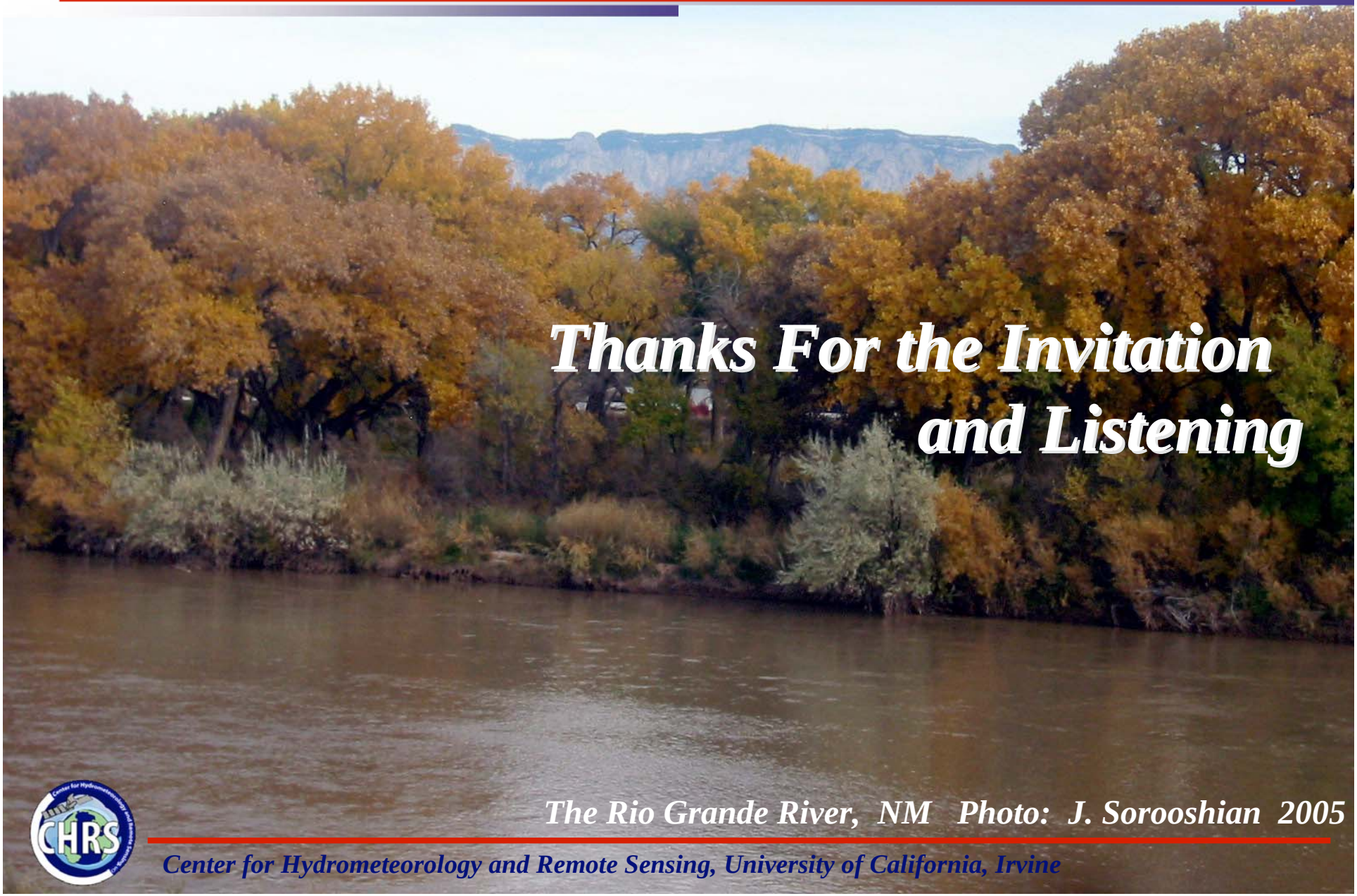
NCEP Forecasted Path

Observed Path



# *If any Message (personal view):*

- ***No question about the importance of RS information for hydromet. Predictions.***
- ***Precipitation is the most critical ( directly "observed" or model generated)***

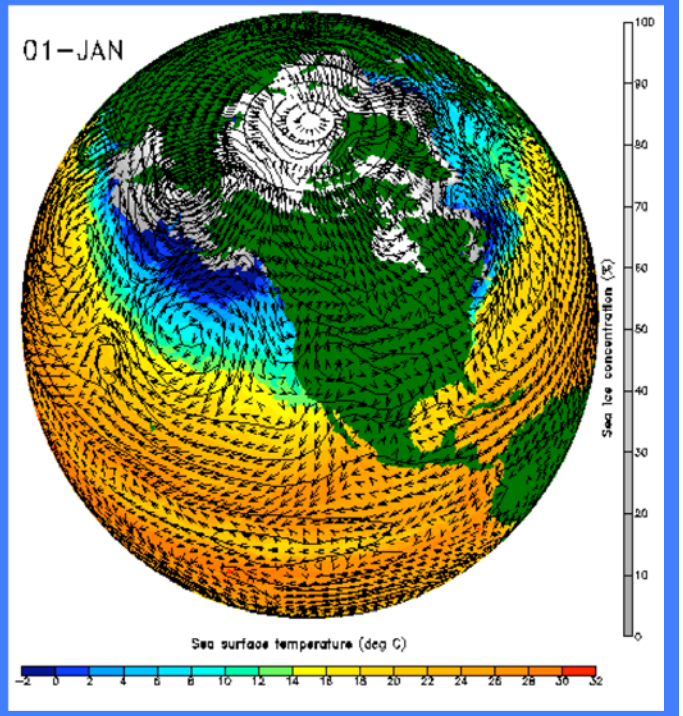



*The Rio Grande River, NM Photo: J. Sorooshian 2005*

# *From Meteorology → to Hydrology*

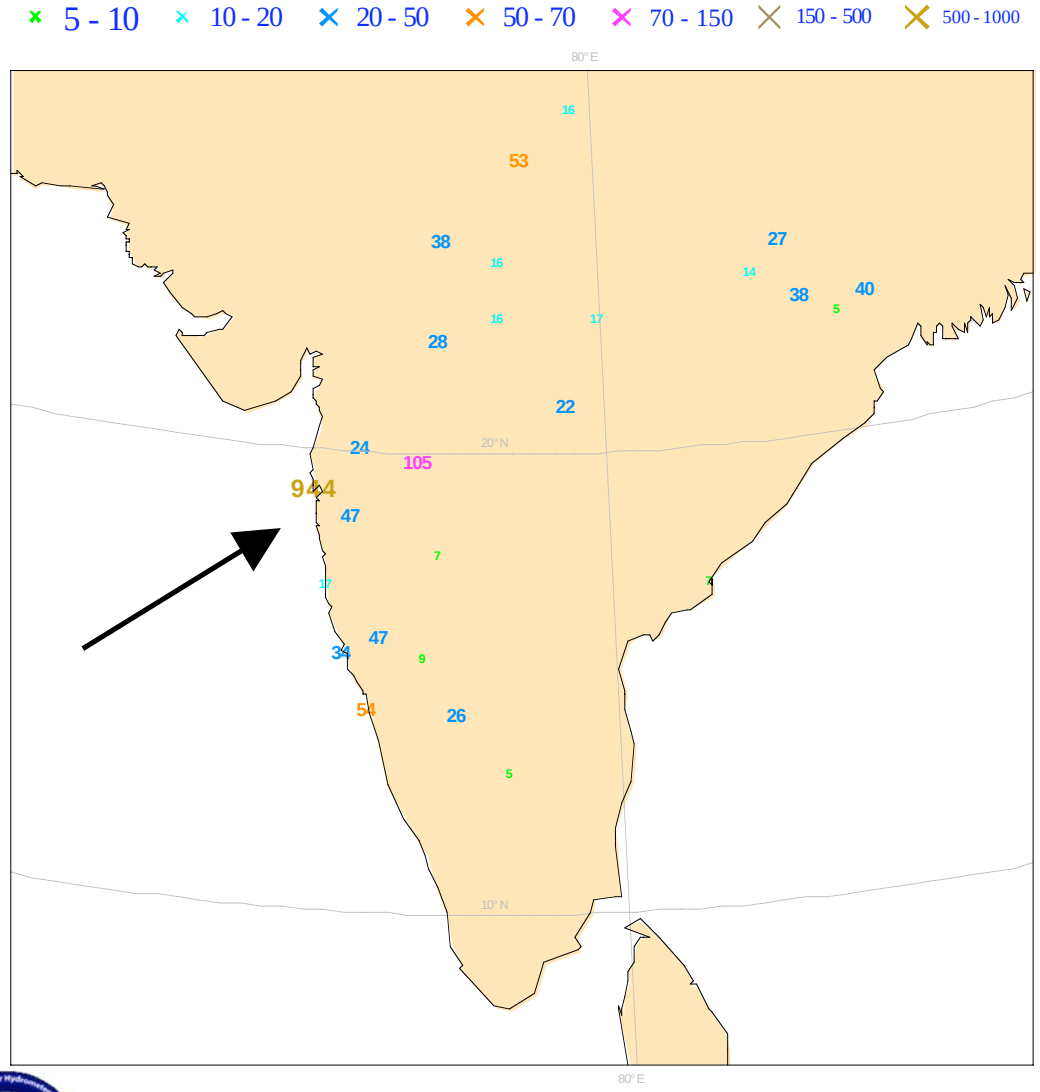
***Some Recent results Of Precipitation estimates from NWP Models:***

***NWP***




***How Accurate Are QPF Estimates for Hydrologic Applications?***

# *Mumbai (26 July 2005): 1 meter of rain in 24 hours*

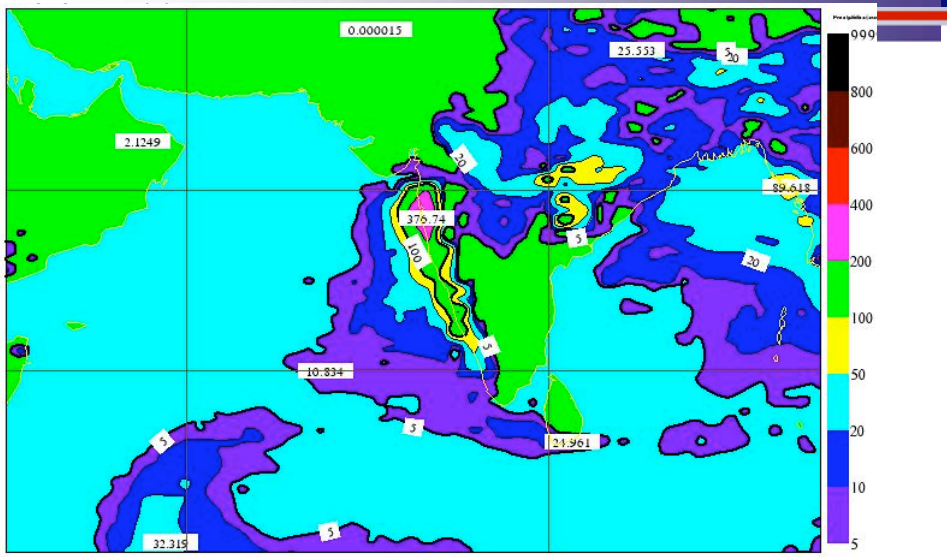




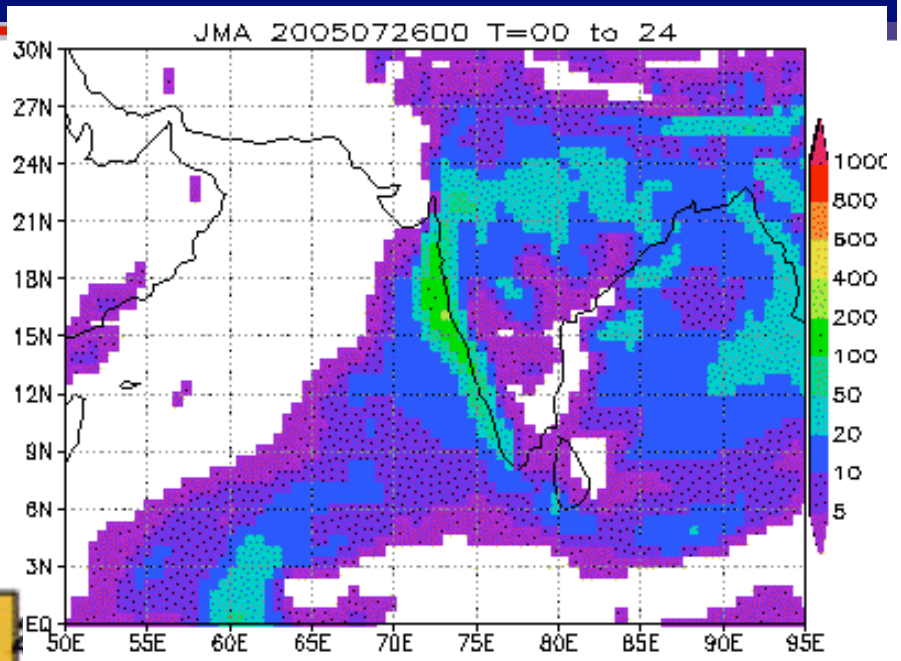
*Source: Martin Miller- GEWEX-SSG, Dakar 2006*

*Center for Hydrometeorology and Remote Sensing, University of California, Irvine*

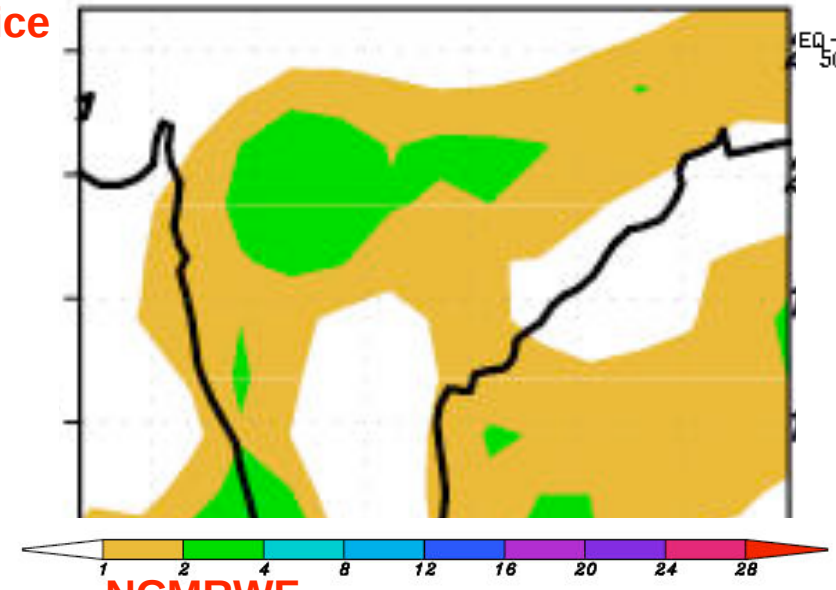
# One Day Forecast




Met Office



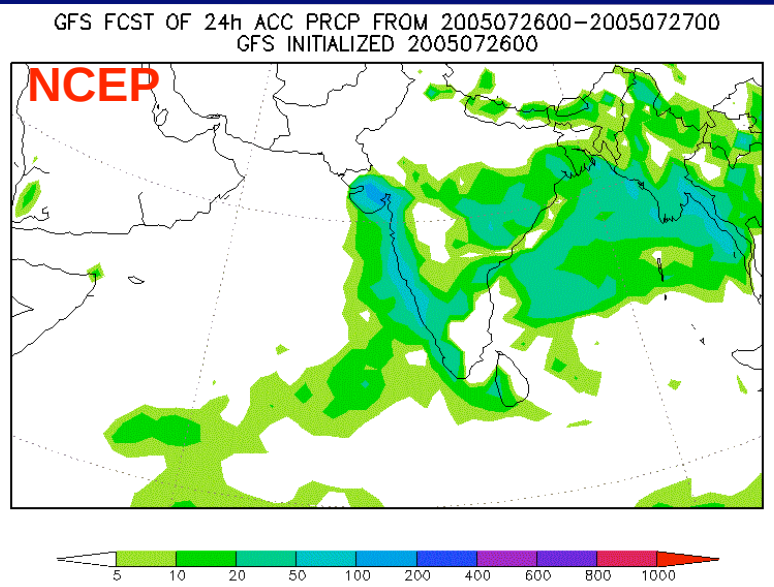

JMA

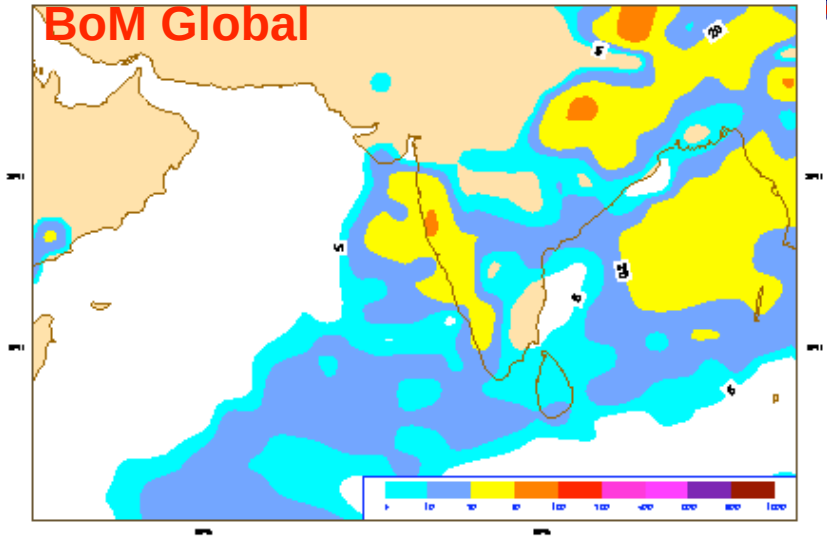


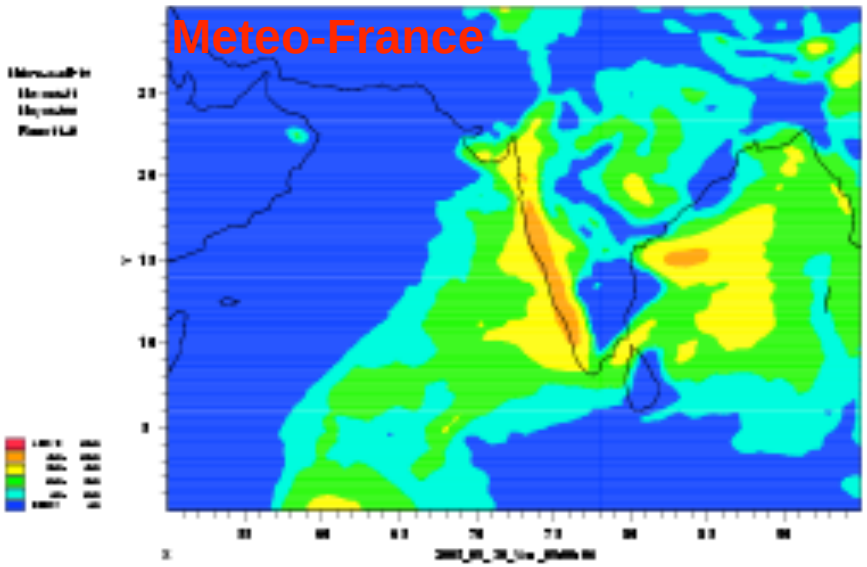

NCMRWF

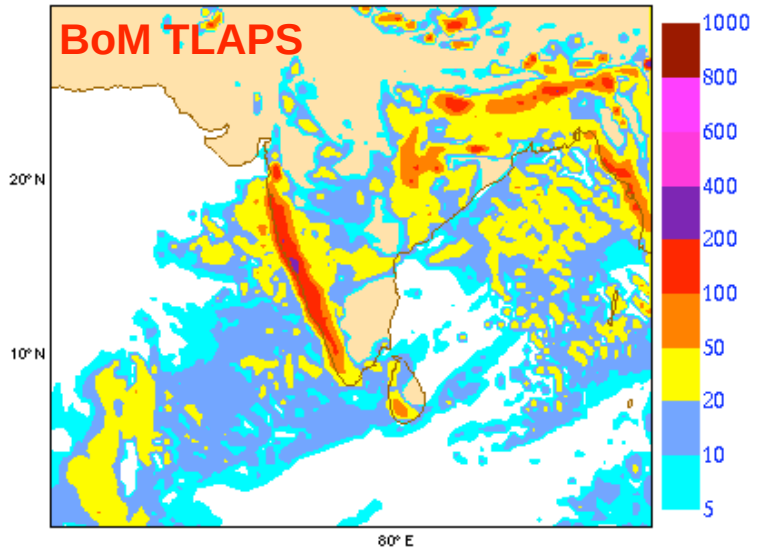
*Source: Martin Miller- GEWEX-SSG, Dakar 2006*

# One Day Forecast



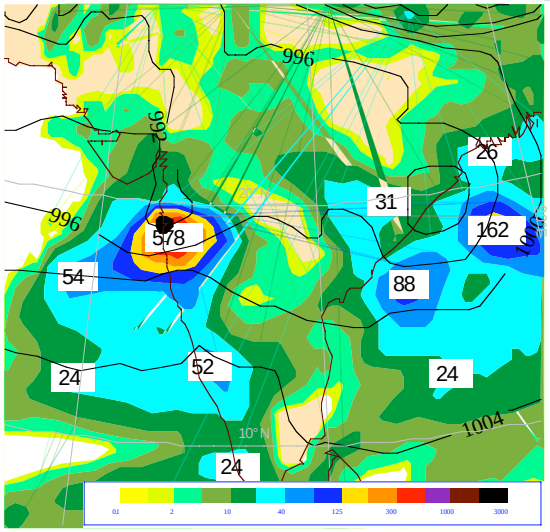

*Source: Martin Miller- GEWEX-SSG, Dakar 2006*

*Center for Hydrometeorology and Remote Sensing, University of California, Irvine*

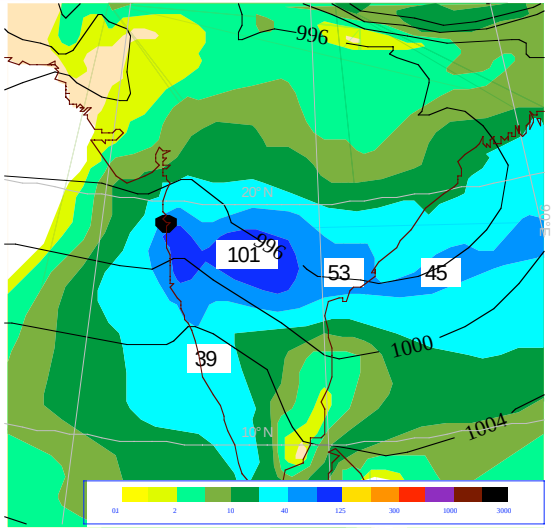
# 9-Day Forecast

Precip forecast (T-suite & E-suite) of deterministic & EPS mean, and probabilities to exceed 200
Forecast from 00UTC Monday 18 Jul 2005 0UTC
event accumulated from +192h to +216h

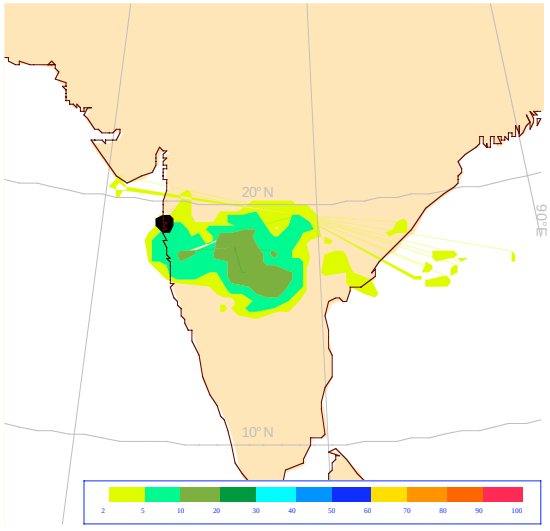
Deterministic, expver: 1



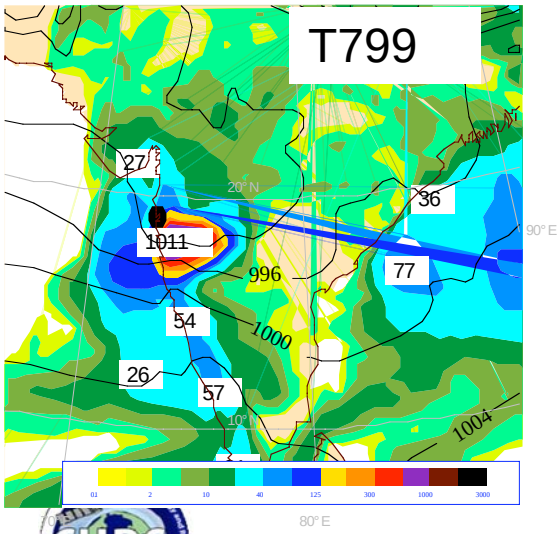

EPS mean, expver: 1



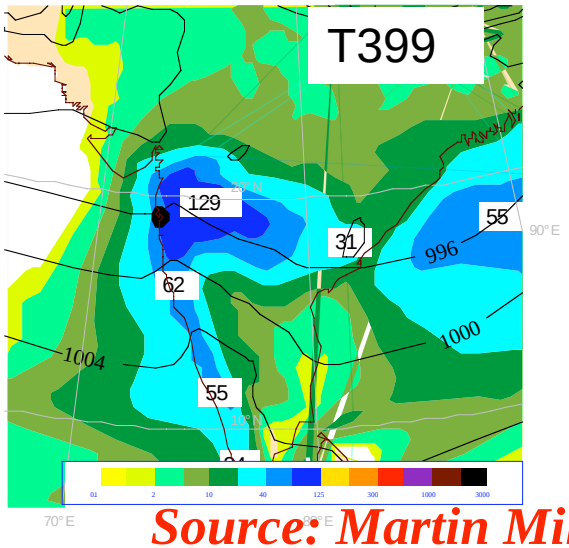

EPS prob. to exceed 200, expver: 1



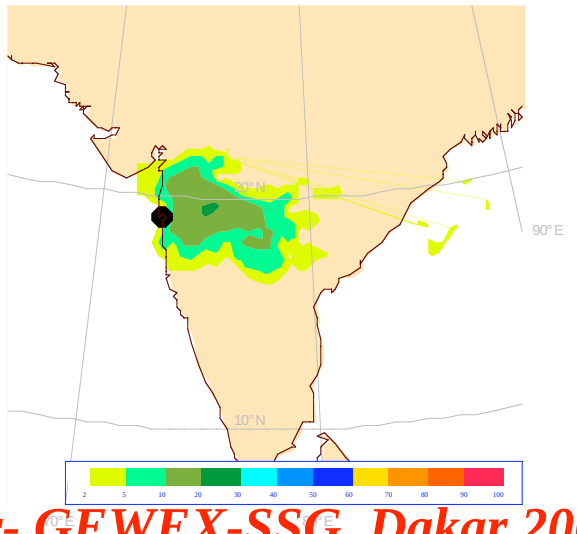

Deterministic, expver: 28




EPS mean, expver: 28




EPS prob to exceed 200, expver: 28



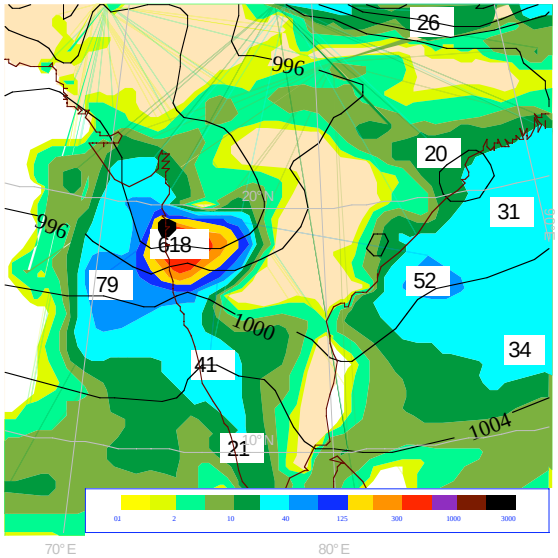

**Source: Martin Miller- GEWEX-SSG, Dakar 2006**

*Center for Hydrometeorology and Remote Sensing, University of California, Irvine*

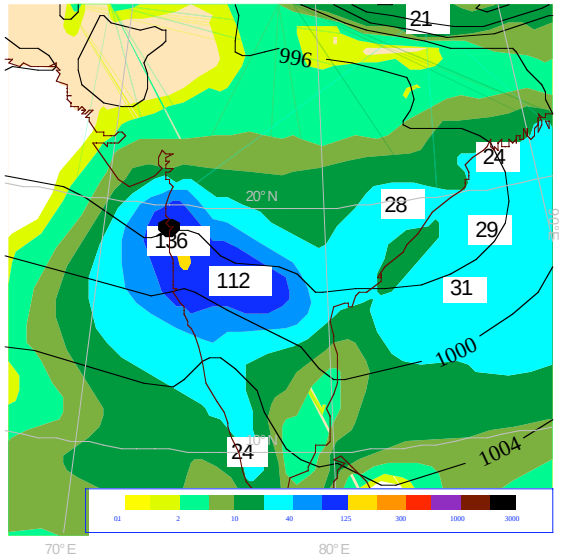
# 7-Day Forecast

precip forecast (O-suite & E-suite) of deterministic & EPS mean, and probabilities to exceed 200
forecast issued on Wednesday 20 Jul 2005 0UTC
e.g. rain accumulated from +144h to +168h

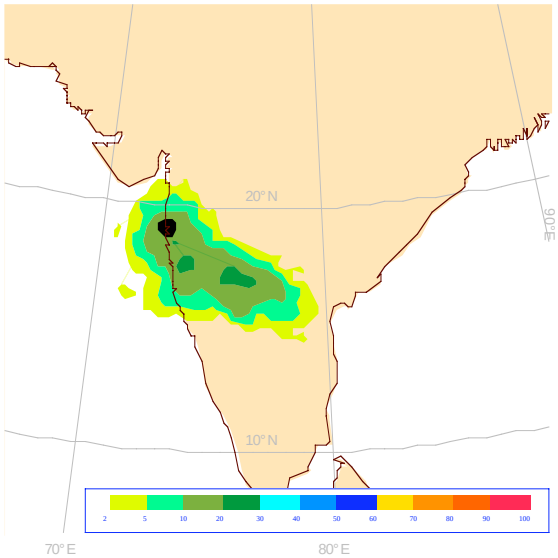
Deterministic, expver: 1



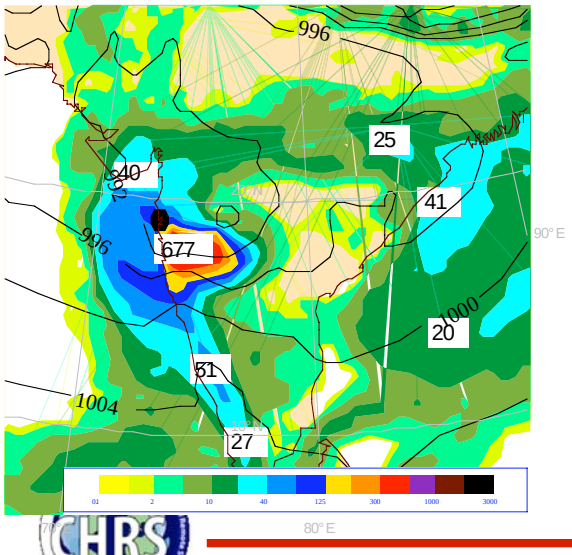

EPS mean, expver: 1



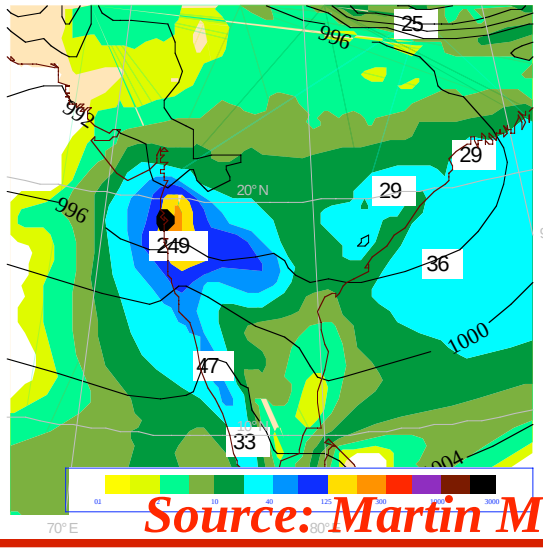

EPS prob. to exceed 200, expver: 1



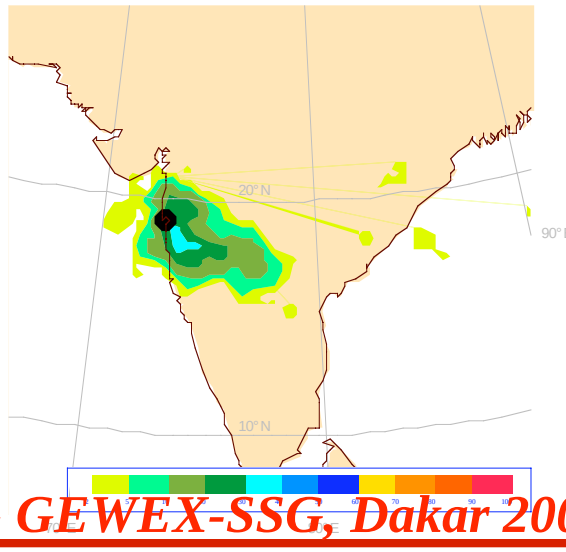

Deterministic, expver: 28




EPS mean, expver: 28




EPS prob to exceed 200, expver: 28



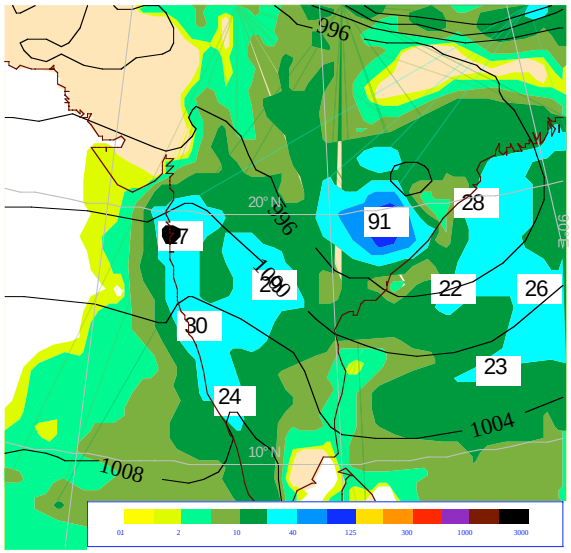

**Source: Martin Miller- GEWEX-SSG, Dakar 2006**


*Center for Hydrometeorology and Remote Sensing, University of California, Irvine*

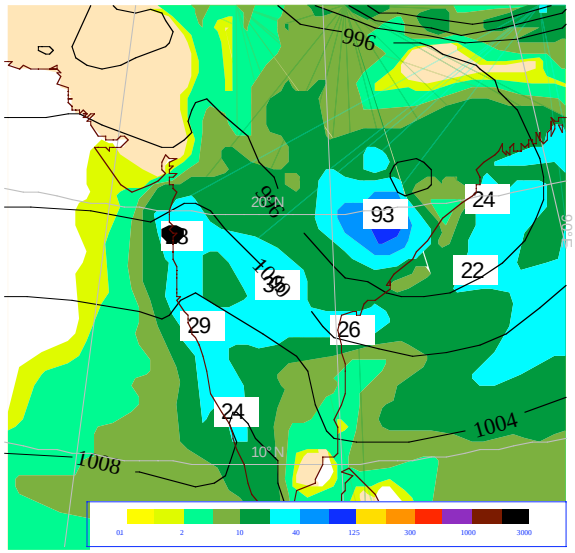
# One Day Forecast

precip forecast (O-suite & E-suite) of deterministic, EPS mean, and probabilities to exceed 200
Forecast is initialized 12UTC Monday 26 Jul 2005 0UTC
event accumulated from +0h to +24h

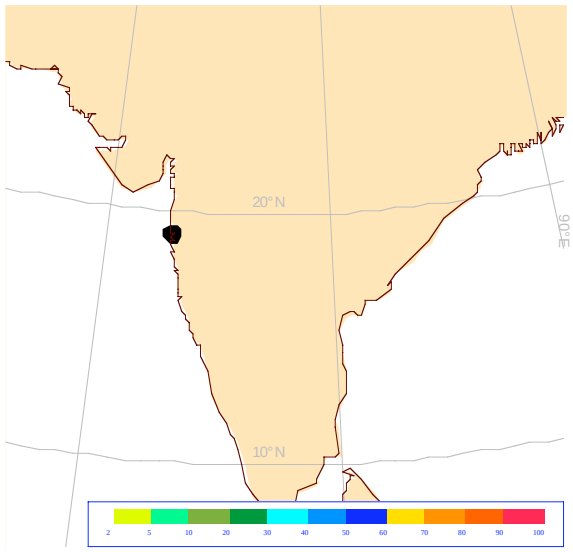
Deterministic, expver: 1



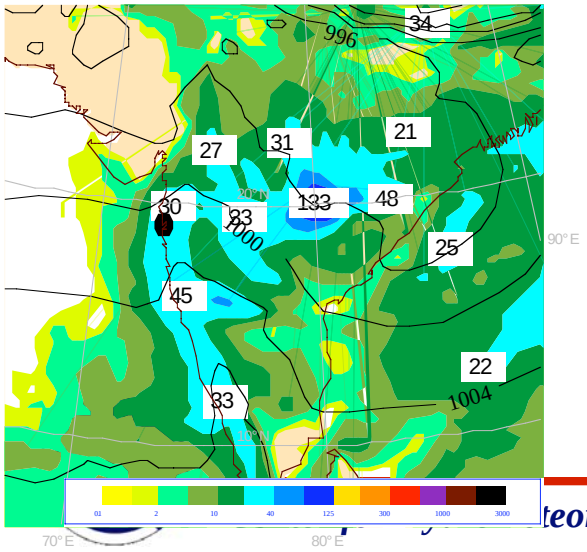

EPS mean, expver: 1



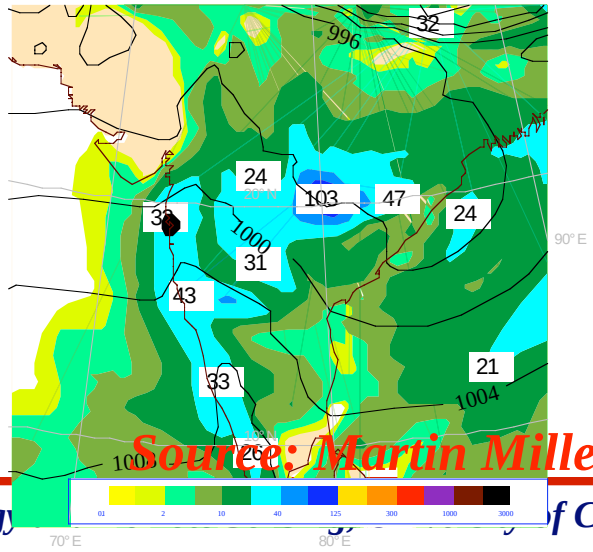

EPS prob. to exceed 200, expver: 1



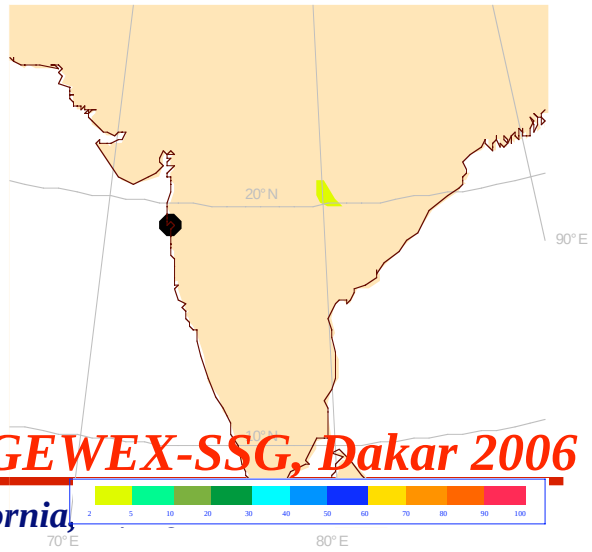

Deterministic, expver: 28




EPS mean, expver: 28




EPS prob to exceed 200, expver: 28




Source: Martin Miller- GEWEX-SSG, Dakar 2006

# CHRS & Affiliates at University of California Irvine (UCI) and Arizona (UA)